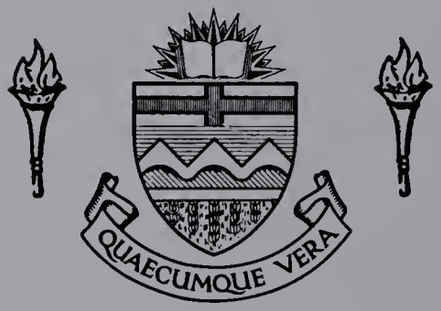

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Factors affecting the nutritive value of rapeseed oil for the chick" submitted by Helen Rosemary Clement, in partial fulfilment of the requirements for the degree of Master of Science.

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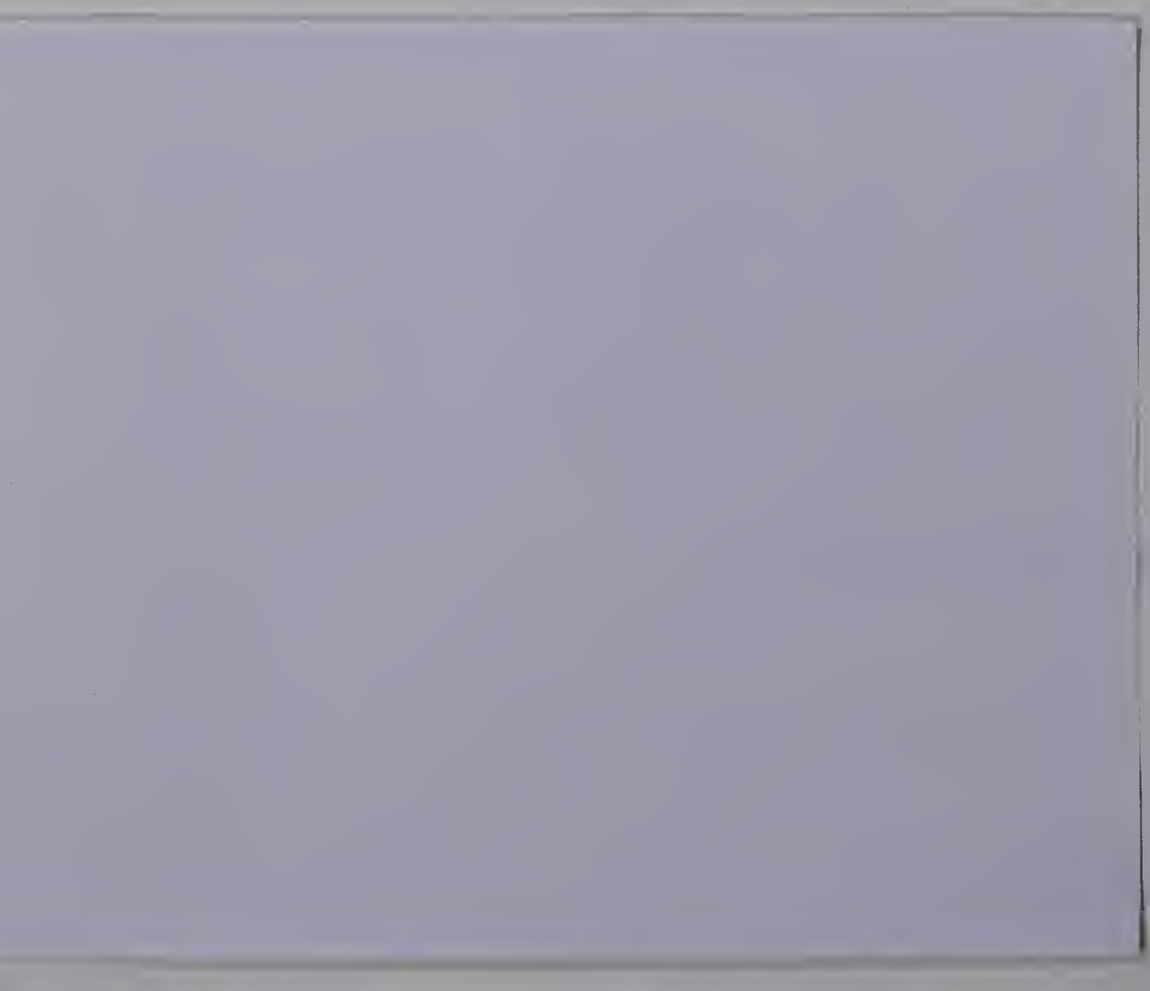

ABSTRACT

Experiments were conducted to study factors affecting the nutritive value of rapeseed oil for the the chick using rate of growth, energetic efficiency and tissue composition as criteria. The diets fed contained high erucic acid rapeseed oil (HER), low erucic acid rapeseed oil (LER) or sunflowerseed oil (SFO), and were formulated by substitution of 10 or 20 parts of the respective oils isocalorically for glucose. Diets containing 15 parts HER or LER and 5 parts palmitic or oleic acid were formulated by similar isocaloric substitution. All chicks were fed the experimental diets from 4 days of age.

When fed for 7 days, diets containing 10 or 20 parts HER caused depressed growth and feed consumption, and reduced fat deposition when compared with similar levels of SFO. Chicks fed diets containing 10 or 20 parts LER for 7 days grew at the same rate and deposited the same amount of fat as chicks fed diets containing similar levels of SFO. The type of oil fed had no effect on the level of cardiac lipid at the end of the 7 days feeding period.

When fed diets containing 10 parts HER, LER or SFO for 24 days, chicks showed similar rates of growth, feed

consumption, heart size and heart fat content. However, consumption of diets containing 10 parts HER caused less carcass fat deposition and less efficient energy utilization than consumption of diets containing similar levels of LER or SFO.

Feeding diets containing 20 parts of oil for 24 or 26 days showed the growth promoting properties of the three oils to differ, with HER giving the lowest, LER an intermediate and SFO the most rapid rate of growth. Results also showed that chicks fed diets containing HER had larger hearts than those fed diets containing similar levels of LER or SFO, but this could not be attributed to increased heart fat content. When pair-fed, chicks fed diets containing 20 parts HER deposited less fat and utilized energy less efficiently than those fed diets containing similar levels of SFO. Fat deposition after feeding diets supplying 20 parts LER was also less than when SFO-containing diets were fed, but these two oils showed the same efficiency of energy utilization.

Diets supplying HER modified with palmitic acid for 26 days caused increased growth and energy utilization, and decreased heart size when compared with the unsupplemented HER. Similar changes were not found in diets containing HER supplemented with oleic acid, or LER supplemented with either palmitic or oleic acid.

After 26 days of feeding, modification of HER by the addition of oleic acid caused less accumulation of erucic and eicosenoic acids in heart and carcass tissue than when palmitic acid was added to HER. No such effect was observed when LER was supplemented with oleic acid.

Irrespective of the type of rapeseed oil or modified oil mixture fed, or of the age of the chick, heart lipids contained less erucic acid than carcass fat, indicating that chick heart tissue is as capable of disposing of erucic acid as carcass tissue. It was also found that irrespective of the diet fed, a greater percentage of erucic acid appeared to be oxidized than of eicosenoic acid. This suggests that either erucic acid is oxidized more rapidly than eicosenoic acid, or that erucic acid is oxidized more rapidly to eicosenoic acid than is eicosenoic acid to oleic acid.

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The author is grateful to all the staff and fellow students in the department who helped to make this study an enjoyable experience. In particular, sincere appreciation is expressed to Dr. Ruth Renner who initiated this research, and patiently provided willing guidance and invaluable help and suggestions during the preparation of the manuscript. Thanks are extended to Mrs. Lorraine Rauhala for her competent technical assistance, and to the other laboratory staff whose co-operation and help contributed to the avoidance of major disasters!

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INTRODUCTION

Although the growth depressing properties of rapeseed oil for the rat were recognized in 1947, it was not until 1970 that rapeseed oil was reported to cause pathological changes in heart and skeletal muscle. As a result of this finding, production of rapeseed in Canada has shifted from varieties containing oil high in erucic acid, to those having a low erucic acid content.

Recently, the question has arisen as to the nutritive value of both high and low erucic acid rapeseed oils for species other than the rat. Since information on the nutritive value of rapeseed oils for the chick is limited, the following studies were conducted to compare the nutritive value of high erucic acid rapeseed oil, low erucic acid rapeseed oil and sunflowerseed oil for the chick using rate of growth, energetic efficiency and tissue composition as the criteria for comparison.

PART 1

GROWTH, ENERGY CONSUMPTION, AND ENERGY UTILIZATION OF CHICKS FED RAPESEED OILS

Literature Review

The growth depressing properties of rapeseed oil were first observed by Boer et al. in 1947 and Deuel et al. in 1948 using the rat as the experimental animal. Since that time numerous studies using various experimental animals have confirmed and extended their findings.

In studies to determine the nutritive value of rapeseed oil for the chick, Sell and Hodgson (1962) showed that rapeseed oil containing 31.5% erucic acid was as effective as comparable levels of soybean oil and sunflowerseed oil in improving weight gain and efficiency of utilization of feed, when incorporated in the diet for 8 weeks at a level of 8%. In contrast, Salmon (1969) found that mixtures containing 25, 50, 75 and 100 parts of rapeseed oil and 75, 50, 25 and 0 parts of soybean oil, respectively, caused small but significant decreases in rate of growth with no significant effect on feed utilization when incorporated into chick diets at a level of 10%. Renner (1967) studied the effect on growth of substituting 5, 10, 15 and 20 parts of rapeseed oil for an equi-caloric amount of glucose in a semi-purified chick diet. Two rapeseed oils containing 24 and 39% erucic

acid were used. Results showed that incorporation of 5 or 10 parts of either oil in the diet did not affect the growth rate. However, when diets containing 20 parts rapeseed oil were fed, growth was depressed, with growth depression being greatest for the oil containing the higher level of erucic acid. Sheppard et al. (1971) have also shown that chicks fed diets containing 16% rapeseed oil grew significantly slower and utilized their feed less efficiently than chicks fed comparable diets containing corn oil. The rapeseed oil used contained 32% erucic acid.

Recently, studies to determine the nutritive value for chicks of new varieties of rapeseed oil containing minimal amounts of erucic acid have been conducted. Walker et al. (1970) compared the nutritive value of refined rapeseed oils containing 1.2, 23 and 32% erucic acid. When incorporated in the diet at a level of 20%, chicks fed the oils containing 1.2% and 32% erucic acid grew at the same rate as the controls, while those fed the oil containing 23% erucic acid grew significantly slower. No explanation was offered for the failure of rapeseed oil containing 32% erucic acid to depress growth. Vogtmann et al. (1973) have also studied the growth and feed efficiency of chicks fed diets containing 5, 10 and 15% of various rapeseed oils, soybean oil and lard. The three experimental rapeseed oils contained 21.4, 2.9 and 2.8% erucic acid. In agreement with Sell and Hodgson (1962) and Renner (1967), results showed

that rapeseed oil, irrespective of erucic acid content promoted growth equal to either soybean oil or lard when fed at the 5 or 10% level. At the 15% level, chicks fed regular rapeseed oil containing 21.4% erucic acid grew significantly slower than chicks fed diets containing 15% lard or 15% soybean oil, but utilized their feed just as efficiently. The growth of chicks fed the low erucic acid varieties at the 15% level was variable. One sample resulted in growth depression, the other permitted growth similar to that of the soybean oil fed controls. No explanation was offered for the variable growth response of chicks fed low erucic acid rapeseed oils.

More extensive studies on the nutritive value of rapeseed oil have been conducted using the rat as the experimental animal. Studies have shown that incorporation of rapeseed oil in excess of 10% by weight of the diet reduced growth and feed consumption (Beare et al., 1957; Thomasson and Boldingh, 1955; Beare et al., 1959b; Hornstra, 1972 and Craig et al., 1963a).

That erucic acid is one of the growth depressing factors in rapeseed oil was shown by Thomasson and Boldingh (1955). Further evidence to support this concept is the finding of Beare et al. (1959a) that substitution of increasing levels of ethyl erucate for corn oil in the diet of weanling rats caused a progressive decrease in growth. Furthermore, low erucic acid rapeseed oils have been shown

to promote as good growth in rats as olive oil (Craig and Beare, 1968) or peanut oil (Rocquelin and Cluzan, 1968).

Another factor in rapeseed oil which may contribute to its growth depressing properties is the unfavorable ratio of saturated fatty acids to unsaturated fatty acids. Beare et al. (1963) showed that increasing the palmitic acid content of rapeseed oil from 3 to 24% by the addition of palm oil significantly increased growth of rats fed oil mixtures containing 20% erucic acid and approximately 16% linoleic acid. However in a subsequent experiment, Beare-Rogers et al. (1972) showed that increasing the level of palmitic acid from 3.5 to 19.1% in a mixture containing 32% erucic acid and 18.7% linoleic acid did not affect food intake or growth. Rocquelin et al. (1971) reported decreased growth of rats when the palmitic acid content of mixtures containing predominantly trierucin or triolein was decreased from 20 to 8 or 10%, respectively. They did not state whether these decreased rates of growth were statistically significant.

Previously, Murray et al. (1958) observed variable effects on growth when the palmitic acid content of mixtures was decreased. They state that the effect of varying the fatty acid composition although reproducible is not large. Since low erucic acid rapeseed oils have been shown to promote good growth (Craig and Beare, 1968; Rocquelin and Cluzan, 1968), it is apparent that a low level of palmitic

acid alone does not decrease its nutritive value.

Reduced feed consumption was shown to accompany growth depression when rats were fed diets containing more than 10% rapeseed oil (Beare et al. 1957; Beare et al., 1959a and 1959b). Beare et al. (1959a) showed that when body weight gains were adjusted for feed consumption by covariance analysis, differences largely disappeared. These results suggest that rapeseed oil decreased growth by decreasing appetite.

The mechanism by which rapeseed oil depressed food intake has been shown to be temporarily mediated. Beare and Beaton (1967) compared the effect on the amount of fat-free diet consumed, by administering rapeseed oil and corn oil apart from the diet by intubation. Results showed that rats intubated with either rapeseed oil or corn oil during the day consumed similar amounts of fat-free diet during the night.

Beare and Beaton (1967) also showed that when the ventro-medial area of the hypothalamus was destroyed, rats fed diets containing rapeseed oil consumed as much food as rats fed corn oil-containing diets. Recently, Hornstra (1972) suggested that the depression in appetite following ingestion of rapeseed oil may be due to thermostatic regulation. He observed that intubation of rapeseed oil stimulated greater basal oxygen consumption than

sunflowerseed oil which could lead to an hyperthermic state, and thus act to stimulate the satiety center. Whether chemical stimuli also are involved in decreasing food intake when rapeseed oil is incorporated in the diet is unknown.

The effect that feeding rapeseed oil has on energy utilization in vivo has received little attention. In some studies but not in all, incorporation of rapeseed oil at levels of 10% or greater has resulted in decreased feed efficiency (g feed/g gain). Since body composition was not studied, energetic efficiency (calories consumed/calorie gained) could not be determined. That energetic efficiency may be decreased is suggested by the finding of Hornstra (1972) that basal oxygen consumption was greater when rats were fed diets in which 60% of the energy was supplied by rapeseed oil rather than by sunflowerseed oil. Other evidence that rapeseed oil may interfere with energy metabolism in at least some tissues is the finding of Houtsmuller et al. (1970) that inclusion of erucic acid in the diet of the rat caused the mitochondria of the heart but not of the liver, to malfunction.

Since information on the nutritive value of rapeseed oils for chicks is limited, the following experiments were conducted to determine the nutritive value of high and low erucic acid rapeseed oils for the chick and to study factors affecting their utilization.

EXPERIMENTS 1 AND 2

The object of these experiments was to compare the nutritive value of low erucic acid rapeseed oil, high erucic acid rapeseed oil and sunflowerseed oil using rate of growth, feed efficiency, and energy utilization as the criteria for comparison.

Materials and methods.

Diets containing high erucic acid rapeseed oil (HER), low erucic acid rapeseed oil (LER), or sunflowerseed oil (SFO), were formulated from the high carbohydrate diet (Table 1), by substituting 10 or 20 parts of the respective oils isocalorically for glucose using the values of 3.64 kcal/g (Hill et al., 1960), 7.37, 8.79 and 8.88 kcal/g (Renner, 1967), for the metabolizable energy content of glucose, HER, LER, and SFO, respectively. Cellulose was added to the diets containing 20 parts of the experimental oil in order to improve the texture and to maintain the caloric density similar to that of diets containing 10 parts of oil (Table 2). The fatty acid composition of the high and low erucic acid oils used in Experiments 1 and 2 is shown in Table 3.

Because the fat containing diets do not total to 100, the level of fat in the diet will be referred to as the

Table 1

Composition of high carbohydrate diet.

Ingredients	%
Constants	
Soybean meal (50% protein)	35.00
Glycine	1.00
Methionine	0.50
Brewers' dried yeast	2.50
Dried whey	2.00
Limestone	1.14
Dicalcium phosphate	1.84
Sodium chloride	0.60
Soybean oil	0.50
Choline chloride (50%)	0.60
Chromic oxide "bread"[1]	1.00
Mineral mixture[2]	0.41
Vitamin mixture[3]	0.28
Antioxidant[4]	0.025
Variable	
Glucose[5]	52.605

[1] Contains 30% Cr_2O_3 in wheat flour.

[2] Mineral mixture supplies in mg/313 kcal of diet: K_2HPO_4,220; $MgSO_4$,115; $MnSO_4 . H_2O$,33.5; $FeSO_4 . 7H_2O$,28; $ZnCO_3$,9.7; $CuSO_4 . 5H_2O$,0.78; KI,0.29; Na_2SeO_3,0.022.

[3] Vitamin mixture supplies in mg/313 kcal of diet: thiamine HCl,1.0; riboflavin,1.0; Ca pantothenate,4.0; biotin,0.04; pyridoxine,2.0; niacin,8.0; folacin 0.3; menadione,0.3; aureomycin,1.0; vitamin B12, 0.000005; vitamin A,1000 IU; vitamin D,150 IU; vitamin E,3.3 IU.

[4] Contains 25% ethoxyquin. Monsanto Chemical Co., St. Louis, Missouri.

[5] Cerelose.

Table 2

Composition of diets

Type of diet		Constant ingredients	Glucose	Cellulose[1]	Total
Oil	Amount				
	g	g	g	g	g
High carbohydrate		47.40	52.60	--	100.00
HER[2]	10	47.40	32.36	--	89.76
LER[3]	10	47.40	28.46	--	85.86
SFO[4]	10	47.40	28.20	--	85.60
HER	20	47.40	12.11	7.00	86.51
LER	20	47.40	4.31	7.00	78.71
SFO	20	47.40	3.82	7.00	78.22

[1] Alpha-floc BW-40, Brown Company, Berlin, New Hampshire.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.

[4] Sunflowerseed oil.

Table 3

Fatty acid composition of oils (Exp.1 and 2).

Fatty acid	Percent of total fatty acids					
	HER[1]		LER[2]		SFO[3]	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
16:0	3.5	2.8	4.5	3.5	6.2	6.7
16:1	-	0.2	-	0.3	-	-
18:0	1.7	1.3	1.7	1.5	4.8	4.7
18:1	21.3	34.0	58.0	55.2	15.3	17.5
18:2	20.2	17.1	19.9	20.3	69.2	69.2
18:3	6.6	7.7	8.4	8.4	0.4	0.4
20:0	1.0	0.5	0.9	2.9	0.7	0.3
20:1	12.0	11.4	2.7	3.2	0.8	0.3
20:2	0.5	0.4	-	-	-	-
22:0	-	-	0.4	-	1.5	0.9
22:1	33.2	24.6	3.5	4.7	1.1	-

[1] High erucic acid rapeseed oil. Obtained from Co-op Vegetable Oils Ltd., Altona, Manitoba, and Western Canadian Seed Processors Ltd., P.O.Box 99, Lethbridge, Alberta, for use in Exp. 1 and 2, respectively.

[2] Low erucic acid rapeseed oil. Obtained from Proctor and Gamble Co. Ltd., Hamilton, Ontario, and Western Canadian Seed Processors Ltd., P.O.Box 99, Lethbridge, Alberta, for use in Exp. 1 and 2, respectively.

[3] Sunflowerseed oil, "Safflo". Gardenland Packers Ltd., Altona, Manitoba.

amount added to maintain the energy equal to its high carbohydrate counterpart.

The chicks were housed in electrically heated thermostatically-controlled battery brooders with raised wire-screen floors in a temperature controlled laboratory. They were reared to 4 days of age on a semi-purified high carbohydrate diet, and then assigned to the experimental groups on the basis of body weight, equalizing both mean body weight and weight distribution among the groups.

Each diet was fed ad libitum to duplicate groups of 10 male crossbred (Dominant White x White Plymouth Rock) chicks from 4 to 11 and 4 to 28 days of age. In addition, duplicate groups were pair-fed diets containing 10 or 20 parts of LER or SFO from 4 to 28 days of age, their feed intakes being restricted to that of chicks fed diets containing 10 or 20 parts HER, respectively. For comparative purposes duplicate groups of chicks were fed a high carbohydrate diet ad libitum. Water was supplied ad libitum and feed wastage was determined daily. Data on growth and feed consumption were obtained weekly.

Excreta from chicks being pair-fed were collected at 24 hour intervals on 3 successive days during the last week of the 24 day experimental period, and kept frozen until processed. Chromium oxide was incorporated in all diets as an index substance, thus avoiding the need for quantitative

measurement of feed intake and quantitative collection of excreta. The methods of processing excreta, conducting chemical analyses for moisture, nitrogen, combustible energy, fat and chromium oxide, and for computing metabolizable energy and fat absorbability from the data have been described previously (Hill and Anderson, 1958; Hill et al., 1960; and Renner and Hill, 1960).

At the termination of the experiment, the chicks were killed with chloroform and the livers and hearts were removed and stored at -29° C until analyzed. After cooling, the contents of the gastro-intestinal tracts were removed and the residual carcasses from each experimental group were frozen, ground, mixed and an aliquot dried by lyophilization. In order that tissue gains could be determined two representative groups of chicks were killed at the beginning of the experiment (4 days of age), and prepared for analysis using the same procedures. Carcass samples of pair-fed chicks were analyzed for protein, fat and moisture as described by Hill and Anderson (1958). Details of heart analysis are given in Experiment 4.

To determine fatty acid composition of dietary fat, methyl esters were prepared by the method of Metcalfe et al. (1966). An Aerograph series 600 gas chromatograph with a four filament thermal conductivity detector (Model 664) was equipped with an aluminum column (10ft.x 1/4in. o.d.), and packed with Silar 5CP on 80-100 mesh acid washed

Chromosorb W. Peaks were identified by comparing retention times of unknown compcnents with those of a known standard, and peak areas computed by geometric approximation. Fraction by weight of a component in a mixture was calculated by the formula proposed by Eastman (1957). The fatty acid composition of the oils used is shown in Table 3.

Results

Data showing average 7 day weight gains, energy consumption and feed efficiency of chicks fed diets in which 10 or 20 parts of HER, LER, or SFO were substituted isocalorically for glucose are summarized in Table 4. Analysis of variance and application of Duncan's multiple range test (Steel and Torrie, 1960) to the data showed that increasing the level of each oil in the diet from 10 to 20 parts decreased both weight gain and energy consumption, significantly. Chicks fed diets containing 10 or 20 parts HER grew significantly slower and consumed significantly less feed than those fed diets containing similar levels of LER or SFO. In contrast, LER promoted the same rate of growth as SFO when either 10 or 20 parts were incorporated in the diet, however chicks fed diets containing 20 parts LER consumed significantly less feed than those fed diets containing 20 parts SFO which resulted in increased feed efficiency.

Comparable data for chicks fed the experimental diets

Table 4

Weight gain, energy consumption and feed efficiency of chicks fed experimental diets ad libitum for 7 days.

Treatment								
Oil	Level	Exp. no.	Weight gain		Kcal consumed[1]		Feed efficiency	
	g		g				kcal/g gain	
High carbohydrate		1	104[3]		412		3.95	
		2	108	106[a]	443	428[bc]	4.11	4.03[d]
HER[2]	10	1	114		438		3.80	
		2	119	117[b]	454	446[c]	3.81	3.80[bc]
LER[2]	10	1	125		463		3.71	
		2	125	125[c]	485	474[d]	3.88	3.80[bc]
SFO[2]	10	1	125		477		3.80	
		2	131	128[c]	504	491[d]	3.86	3.83[c]
HER	20	1	102		372		3.66	
		2	102	102[a]	388	380[a]	3.80	3.72[b]
LER	20	1	115		423		3.69	
		2	111	113[b]	395	409[b]	3.54	3.62[a]
SFO	20	1	113		432		3.82	
		2	120	116[b]	458	445[c]	3.82	3.82[c]

[1] Calculated using determined metabolizable energy values for the diets.

[2] See footnotes 2 to 4, Table 2.

[3] Values are averages of duplicate groups. Underlined values are averages of duplicate experiments. Values without a common letter in their superscript are significantly different ($P<0.05$).

for 24 days are summarized in Table 5. Analysis of variance and application of Duncan's multiple range test (Steel and Torrie, 1960) to the data showed similar growth, energy consumption and feed efficiency in chicks fed diets containing 10 parts of either HER, LER or SFO. However, when chicks were fed diets containing 20 parts HER, growth and feed consumption were significantly less than in chicks fed similar levels of LER or SFO, but feed was utilized as efficiently. The effect of incorporating 20 parts LER in the diet was similar to the 7 day feeding regimen in that chicks grew as well as those fed 20 parts SFO, consumed significantly less feed and utilized it more efficiently.

When energy intake of chicks fed diets containing 20 parts LER or SFO was limited to that of chicks fed 20 parts HER, growth rates did not differ significantly (Table 6). However, chicks fed diets containing 20 parts HER utilized their feed more efficiently than those pair-fed diets containing 20 parts SFO when calories consumed per gram gained was used as the index of efficiency. The reason why chicks fed diets containing 10 parts HER gained significantly more weight than those pair-fed diets containing 10 parts SFO is not apparent.

Data showing energy consumption, gain in carcass fat and protein, and energy utilization of chicks pair-fed the experimental diets for 24 days are summarized in Table 7. Analysis of variance and application of Duncan's multiple

Table 5

Weight gain, energy consumption and feed efficiency of chicks fed experimental diets ad libitum for 24 days.

Treatment Oil	Level	Exp. no.	Weight gain	Kcal consumed[1]	Feed efficiency
	g		g		kcal/g gain
High carbohydrate		1	484[3]	2176	4.45
		2	468	2234	4.78
			476[b]	2205[bc]	4.62[c]
HER[2]	10	1	532	2448	4.60
		2	511	2274	4.44
			522[de]	2361[de]	4.52[bc]
LER[2]	10	1	550	2380	4.32
		2	537	2456	4.58
			543[e]	2418[de]	4.45[ab]
SFO[2]	10	1	531	2443	4.64
		2	544	2428	4.46
			537[e]	2436[e]	4.55[bc]
HER	20	1	435	1920	4.42
		2	429	1916	4.47
			432[a]	1918[a]	4.45[ab]
LER	20	1	494	2217	4.48
		2	477	2010	4.22
			486[bc]	2114[b]	4.35[a]
SFO	20	1	502	2290	4.57
		2	509	2326	4.58
			505[cd]	2308[cd]	4.57[bc]

[1] Calculated using determined metabolizable energy values for the diets.

[2] See footnotes 2 to 4, Table 2.

[3] Values are averages of duplicate groups. Underlined values are averages of duplicate experiments. Values without a common letter in their superscript are significantly different ($P<0.05$).

Table 6

Weight gain, energy consumption and feed efficiency of chicks pair-fed experimental diets for 24 days.

Treatment					
Oil	Level	Exp. no.	Weight gain	Kcal consumed[1]	Feed efficiency
	g		g		kcal/g gain
HER[2]	10	1	532[3]	2448	4.60
		2	511	2274	4.44
			522[c]	2361[c]	4.52[ab]
LER[2]	10	1	540	2440	4.52
		2	485	2273	4.68
			513[bc]	2356[c]	4.60[ab]
SFO[2]	10	1	498	2428	4.90
		2	497	2316	4.66
			498[b]	2372[c]	4.78[b]
HER	20	1	435	1920	4.42
		2	429	1916	4.47
			432[a]	1918[a]	4.45[a]
LER	20	1	448	2084	4.70
		2	400	1790	4.48
			424[a]	1937[ab]	4.59[ab]
SFO	20	1	446	2118	4.74
		2	391	1872	4.78
			419[a]	1995[b]	4.76[b]

[1] Calculated using determined metabolizable energy values for the diets

[2] See footnotes 2 to 4, Table 2.

[3] Values are averages of duplicate groups. Underlined values are averages of duplicate experiments. Values without a common letter in their superscript are significantly different ($P<0.05$).

Table 7

Energy consumption, carcass gain of fat and protein, and energy utilization of chicks pair-fed experimental diets for 24 days.

Treatment		Exp. no.	Kcal consumed[1]	Carcass gain		Energy utilization[2]
				Fat	Protein	
Oil	Level					
	g			g	g	
HER[3]	10	1	2448[4]	40.5	103.0	2.54
		2	2274	42.6	95.9	2.41
			2361[c]	41.5[c]	99.4[b]	2.48[b]
LER[3]	10	1	2440	47.0	114.4	2.24
		2	2273	45.6	91.0	2.40
			2356[c]	46.3[d]	102.7[c]	2.32[a]
SFO[3]	10	1	2428	49.0	113.4	2.20
		2	2316	44.6	93.1	2.44
			2372[c]	46.8[d]	103.2[c]	2.32[a]
HER	20	1	1920	27.4	83.0	2.65
		2	1916	28.2	76.7	2.74
			1918[a]	27.8[a]	79.8[a]	2.69[c]
LER	20	1	2084	32.8	90.2	2.54
		2	1790	28.7	73.9	2.60
			1937[ab]	30.7[a]	82.0[a]	2.57[b]
SFO	20	1	2118	38.3	89.8	2.44
		2	1872	35.1	74.2	2.50
			1995[b]	36.7[b]	82.0[a]	2.47[b]

[1] Calculated using determined metabolizable energy values for the diets.

[2] Kilocalories of metabolizable energy consumed/kilocalorie gained.

[3] See footnotes 2 to 4, Table 2.

[4] Values are averages of duplicate groups. Underlined values are averages of duplicate experiments. Values without a common letter in their superscript are significantly different ($P<0.05$).

range test (Steel and Torrie, 1960) to the data showed that chicks fed diets containing 10 parts HER deposited significantly less carcass fat and protein, and utilized energy less efficiently than those fed diets containing 10 parts LER or SFO, when calories consumed per calorie gained was used as the criterion of energetic efficiency. When fed diets containing 20 parts of HER, chicks deposited less fat than those pair-fed diets containing 20 parts SFO; energy was utilized less efficiently than by chicks pair-fed diets containing similar amounts of LER or SFO. Results also showed that the energy in diets containing 10 or 20 parts LER was utilized as efficiently as diets containing 10 or 20 parts SFO, respectively.

The data summarized in Table 8 show that after only 7 days of ad libitum feeding, chicks fed diets containing 10 or 20 parts HER deposited significantly less fat and protein in the carcass than chicks fed comparable levels of SFO. This reduced fat deposition contributed to the reduced efficiency of energy utilization in chicks fed diets containing 20 parts HER when compared with SFO fed controls. In contrast, chicks fed diets containing either 10 or 20 parts LER deposited similar amounts of fat and utilized energy just as efficiently as chicks fed diets containing 10 or 20 parts SFO.

Table 8

Energy consumption, carcass gain of fat and protein, and energy utilization of chicks fed experimental diets ad-libitum for 7 days (Exp.2).

Treatment		Kcal consumed[1]	Carcass gain		Energy utilization[2]
Oil	Level		Fat	Protein	
	g		g	g	
High carbohydrate		443[4] b	11.0 b	17.4 b	2.18 b
HER[3]	10	454 b	12.5 bc	19.1 c	2.02 ab
LER[3]	10	485 cd	13.7 cd	19.5 c	2.02 ab
SFO[3]	10	504 d	15.0 d	20.9 d	1.94 a
HER	20	388 a	8.0 a	15.6 a	2.37 c
LER	20	395 a	11.1 b	16.7 b	1.98 a
SFO	20	458 bc	13.3 bcd	18.7 c	1.98 a

[1] Calculated using determined metabolizable energy values for the diets.

[2] Kilocalories of metabolizable energy consumed/kilocalorie gained.

[3] See footnotes 2 to 4, Table 2.

[4] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

Discussion

The finding in the foregoing experiments that the inclusion of 20 but not 10 parts HER in the diet of the chick depressed growth at 24 days is in agreement with results reported for the chick by Renner (1967), Vogtmann et al. (1973) and Sell and Hodgson (1962); and for the rat by Beare et al. (1957); Rocquelin et al. (1968) and Kramer et al. (1973).

Since differences in growth rate disappeared when chicks were pair-fed diets containing 20 parts of either HER, LER or SFO it appears that HER depressed growth by decreasing appetite. Previously, Beare et al. (1959a) observed that differences in rate of growth of rats fed diets containing 20 parts rapeseed oil largely disappeared when body weight gains were adjusted for food consumption by covariance analysis. They suggested that rapeseed oil decreased growth by decreasing appetite.

The reason why appetite was depressed when chicks were fed diets containing 20 parts HER is unknown. Since chicks fed diets containing 20 parts HER deposited less fat and utilized energy less efficiently than chicks pair-fed diets containing 20 parts SFO, they must be losing more energy as heat. Whether increased heat production when consuming diets containing HER stimulates the satiety center and reduces food intake is unknown. Support for this concept

has recently been provided by Hornstra et al. (1972). They observed that intubation of rapeseed oil stimulated greater basal oxygen consumption in rats than sunflowerseed oil, and suggested that ingestion of rapeseed oil may lead to hyperthermia.

The finding that LER supported growth equal to that of SFO when incorporated in the diet at a level of 20%, supports the finding of Walker et al. (1970) that chicks fed diets containing 20% LER grew at the same rate as chicks fed diets containing 20% prime tallow. The reason why chicks fed diets containing 20 parts LER deposited less fat than chicks pair-fed diets containing 20 parts SFO is not apparent. Although differences in fat deposition were significant, they were not great enough to cause significant differences in energetic efficiency.

Fatty acid analysis (Table 3) showed that the HER and LER used in these experiments contained similar amounts of palmitic and stearic acids. Major differences between HER and LER were in their content of erucic acid, gadoleic acid and oleic acid. Calculations indicate that in Experiments 1 and 2, diets containing 20 parts HER contained 6.6 and 5% erucic acid, respectively, while diets containing 20 parts LER contained 0.7 and 0.9% erucic acid, respectively. The inverse relationship between erucic acid content of the diet and growth of chicks observed in these experiments supports the theory that erucic acid is one of the major growth

depressing factors in rapeseed oil.

No relationship between intake of saturated fatty acids and growth of chicks is apparent in this experiment, since chicks fed LER diets containing approximately 7.7% saturated fatty acids grew faster than chicks fed HER diets containing approximately 5.4% saturated fatty acids and at the same rate as chicks fed SFO diets containing approximately 12.9% saturated fatty acids.

EXPERIMENT 3

Results of the preceding experiments showed that chicks fed diets containing 20 parts high erucic acid rapeseed oil consumed less feed, grew more slowly and utilized energy less efficiently than chicks fed diets containing either 20 parts of low erucic acid rapeseed oil or sunflowerseed oil. The following experiment was conducted to determine the effects on growth, feed efficiency and energy utilization of altering the ratio of saturated to unsaturated fatty acid in high and low erucic acid rapeseed oils.

Materials and methods.

Diets containing 20 parts high erucic acid rapeseed oil (HER), 20 parts low erucic acid rapeseed oil (LER), 20 parts sunflowerseed oil (SFO) or mixtures composed of 15 parts HER

or LER and 5 parts palmitic acid or oleic acid were formulated from the high carbohydrate diet (Table 1), by substituting the respective oil or oil mixture isocalorically for glucose. Metabolizable energy values used in formulating the diets were 3.64 kcal/g (Hill et al. 1960), 7.37, 8.79, 8.88 kcal/g (Renner, 1967), 4.59 and 8.31 kcal/g (Renner and Hill, 1961), for glucose, HER, LER, SFO, palmitic acid and oleic acid, respectively. Cellulose was added to improve the texture of the experimental diets in an amount to maintain caloric density similar to the diets fed in Experiments 1 and 2. The composition of the diets fed is shown in Table 9.

Each diet was fed ad libitum to duplicate groups of 10 male crossbred (Dominant White x White Plymouth Rock) chicks from 4 to 30 days of age. In addition, duplicate groups of chicks were pair-fed the experimental diets from 4 to 11 and 4 to 30 days of age, their feed intake being restricted to that of chicks fed the diets containing 20 parts HER.

The methods of allotment, feeding and housing were the same as in Experiments 1 and 2. Data on growth and feed consumption were obtained weekly and feed wastage was determined daily. Fecal collections were made at 24 hour intervals on 3 successive days during the last week of the 26 day experimental feeding period and kept frozen until processed. The methods of processing excreta, conducting chemical analyses and for computing metabolizable energy

Table 9

Composition of diets.

	Level			Constant ingredients	Glucose	Cellulose[1]	Total
	Oil	Palmitic acid	Oleic acid				
	g	g	g	g	g	g	g
SFO[2]	20	-	-	47.40	3.82	7.00	78.22
HER[3]	20	-	-	47.40	12.11	7.00	86.51
HER	15	5	-	47.40	15.92	7.00	90.32
HER	15	-	5	47.40	10.81	7.00	85.21
LER[4]	20	-	-	47.40	4.31	7.00	78.71
LER	15	5	-	47.40	10.08	7.00	84.48
LER	15	-	5	47.40	4.97	7.00	79.37

[1] Alpha-floc BW-40. Brown Company, Berlin, New Hampshire.

[2] Sunflowerseed oil, "Safflo". Gardenland Packers, Ltd., Altona, Manitoba.

[3] High erucic acid rapeseed oil. Co-op Vegetable Oils Ltd., Altona, Manitoba.

[4] Low erucic acid rapeseed oil. Western Canadian Seed Processors Ltd., Lethbridge, Alberta.

from the data have been described previously (Exp. 1 and 2).

The fatty acid composition of oils and fatty acids were determined as described in Experiment 1 and 2. The fatty acid composition of the oils fed is shown in Table 10.

Results

Data showing average 26 day weight gains of chicks fed diets in which 20 parts of the fat mixtures were substituted isocalorically for glucose are summarized in Table 11. Analysis of variance and application of Duncan's multiple range test (Steel and Torrie, 1960) to the data showed that chicks fed diets containing 20 parts HER or LER grew significantly slower and consumed less feed than chicks fed diets containing 20 parts SFO. The reason why chicks fed diets supplying 20 parts LER grew slower than chicks fed diets containing SFO and at the same rate as chicks fed diets containing HER in this experiment, but not in Experiments 1 and 2 is unknown.

Analysis of variance of the factorial arrangement of treatments also showed that while supplementation of the rapeseed oils with palmitic acid significantly increased both growth and caloric consumption, supplementation with oleic acid did not affect either growth or caloric consumption, significantly. These results indicate that the increase in growth observed on addition of palmitic acid was

Table 10
Fatty acid composition of oils (Exp.3).

Fatty acid	Percent of total fatty acids						
	SFO[1]	HER[1]	LER[1]	HER + Fatty acid		LER + Fatty acid	
				Palmitic	Oleic	Palmitic	Oleic
14:0	-	-	-	-	0.7	-	0.7
16:0	6.9	3.7	3.7	27.8	4.2	27.8	4.2
16:1	-	-	0.3	-	1.6	0.2	1.8
18:0	4.4	1.9	1.4	1.4	1.7	1.0	1.4
18:1	16.4	23.4	58.1	17.6	35.3	43.6	61.3
18:2	71.0	20.9	20.6	15.7	18.0	15.5	17.7
18:3	-	5.3	8.0	4.0	4.0	6.0	6.0
20:0	0.4	-	-	-	-	-	-
20:1	0.2	11.4	3.5	8.5	8.7	2.6	2.8
20:4	0.7	-	-	-	-	-	-
22:1	-	33.4	4.4	25.0	25.0	3.3	3.3
Unknown	-	-	-	-	0.8	-	0.8

[1] See footnotes 2 to 4, Table 9.

Table 11

Weight gain, energy consumption and feed efficiency of chicks fed experimental diets ad libitum for 26 days (Exp.3).

Dietary level			Weight gain	Kcal consumed[1]	Feed efficiency
Oil	Palmitic acid	Oleic acid			
g	g	g	g		kcal/g gain
SFO[2]	20	-	-	595[3]^{c}	2864^{c}	4.81^{c}
HER[2]	20	-	-	506^{a}	2414^{a}	4.76^{c}
HER	15	5	-	582^{bc}	2656^{abc}	4.56^{ab}
HER	15	-	5	533^{ab}	2516^{ab}	4.72^{bc}
LER[2]	20	-	-	538^{ab}	2458^{ab}	4.57^{ab}
LER	15	5	-	572^{bc}	2696^{bc}	4.71^{bc}
LER	15	-	5	563^{bc}	2544^{ab}	4.52^{a}

[1] Calculated using determined metabolizable energy values for the diets.

[2] See footnotes 2 to 4, Table 9.

[3] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

due to this acid and not to the reduced level of rapeseed oil in the diet.

Summarized in Table 12 are data showing weight gain, energy consumption and feed efficiency of chicks pair-fed the experimental diets for 7 and 26 days. The data show that the growth stimulating effect of palmitic acid when added to HER disappeared when feed intakes were restricted to that of chicks fed diets containing the unsupplemented HER. The reason why chicks fed the HER containing diet ad libitum for 26 days grew faster than chicks pair-fed an equicaloric amount of SFO, LER, HER+palmitic acid, LER+oleic acid or LER+palmitic acid is unknown. A similar trend was observed in Experiments 1 and 2.

Data on carcass composition summarized in Table 13 show that chicks fed diets containing 20 parts HER for 26 days deposited less fat than chicks pair-fed diets containing 20 parts SFO. In contrast, chicks fed diets containing 20 parts LER for 26 days deposited fat in an amount intermediate to that of chicks pair-fed diets containing SFO or HER, and not significantly different from either of these oils. As in Experiments 1 and 2, chicks fed diets containing 20 parts HER utilized energy less efficiently than chicks fed diets containing 20 parts of either LER or SFO. The data also showed that chicks fed diets containing 20 parts LER utilized energy just as efficiently as chicks fed diets containing 20 parts SFO.

Table 12

Weight gain, energy consumption and feed efficiency of chicks pair-fed experimental diets for 7 or 26 days (Exp.3).

Dietary level			Weight gain		Kcal consumed[1]		Feed efficiency	
Oil	Palmitic acid	Oleic acid	7 day	26 day	7 day	26 day	7 day	26 day
g	g	g	g	g			kcal/g gain	
SFO[2]	20	-	-	92[3a]	486[a]	410[ab]	2392[cd]	4.46[b]	4.92[b]
HER[2]	20	-	-	99[a]	506[b]	419[b]	2414[cd]	4.22[ab]	4.76[ab]
HER	15	5	-	95[a]	490[a]	410[ab]	2352[bc]	4.32[ab]	4.80[ab]
HER	15	-	5	92[a]	496[ab]	423[b]	2448[d]	4.62[b]	4.94[b]
LER[2]	20	-	-	99[a]	482[a]	392[ab]	2298[ab]	3.96[a]	4.77[ab]
LER	15	5	-	96[a]	480[a]	404[ab]	2358[bc]	4.21[ab]	4.91[b]
LER	15	-	5	99[a]	486[a]	386[a]	2253[a]	3.91[a]	4.64[a]

[1] Calculated using determined metabolizable energy values for the diets.

[2] See footnotes 2 to 4 Table 9.

[3] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

Table 13

Energy consumption, carcass gain of fat and protein, and energy utilization of chicks pair-fed experimental diets for 26 days (Exp.3).

Dietary level			Kcal consumed[1]	Carcass gain		Energy utilization[2]
Oil	Palmitic acid	Oleic acid		Fat	Protein	
g	g	g		g	g	
SFO[3]	20	-	-	2392[4] ^{cd}	56.3 ^{b}	93.6 ^{a}	2.26 ^{a}
HER[3]	20	-	-	2414 ^{cd}	46.6 ^{a}	93.1 ^{a}	2.50 ^{b}
HER	15	5	-	2352 ^{bc}	52.7 ^{ab}	91.2 ^{a}	2.32 ^{a}
HER	15	-	5	2448 ^{d}	51.9 ^{ab}	92.2 ^{a}	2.42 ^{ab}
LER[3]	20	-	-	2298 ^{ab}	50.4 ^{ab}	90.6 ^{a}	2.32 ^{a}
LER	15	5	-	2358 ^{bc}	49.5 ^{ab}	91.8 ^{a}	2.39 ^{ab}
LER	15	-	5	2253 ^{a}	51.8 ^{ab}	90.7 ^{a}	2.26 ^{a}

[1] Calculated using determined metabolizable energy values for the diets.

[2] Kilocalories of metabolizable energy consumed/kilocalorie gained.

[3] See footnotes 2 to 4, Table 9.

[4] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

Results also indicated that modification of the fatty acid composition of HER by the addition of either palmitic or oleic acid increased fat deposition, but the increases were not great enough to be significant ($P>0.05$); however, the addition of palmitic acid to HER increased energetic efficiency significantly and permitted chicks to utilize energy as efficiently as chicks pair-fed diets containing LER or SFO.

The data summarized in Table 14 show that after only 7 days of pair-feeding, chicks fed diets containing 20 parts HER deposited significantly less fat and utilized energy less efficiently than chicks pair-fed diets containing similar levels of LER or SFO. The data also show that chicks fed diets containing 20 parts LER deposited similar amounts of fat and utilized energy just as efficiently as chicks fed a similar diet containing SFO. Modification of the fatty acid composition of either the high or low erucic acid rapeseed oil by the addition of palmitic or oleic acid had no significant effect on either the amount of fat deposited or the efficiency of utilization of the energy after 7 days.

Table 14

Energy consumption, carcass gain of fat and protein, and energy utilization of chicks pair-fed experimental diets for 7 days (Exp.3).

Dietary level			Kcal consumed[1]	Carcass gain		Energy utilization[2]
Oil	Palmitic acid	Oleic acid		Fat	Protein	
g	g	g		g	g	
SFO[3] 20	-	-	410[4] ^{ab}	10.7 ^{bc}	15.5 ^{a}	2.18 ^{abc}
HER[3] 20	-	-	419 ^{b}	7.4 ^{a}	16.0 ^{ab}	2.60 ^{d}
HER 15	5	-	410 ^{a}	8.5 ^{ab}	15.9 ^{ab}	2.40 ^{bcd}
HER 15	-	5	423 ^{b}	8.7 ^{ab}	15.2 ^{a}	2.52 ^{cd}
LER[3] 20	-	-	392 ^{ab}	10.0 ^{bc}	16.6 ^{b}	2.08 ^{ab}
LER 15	5	-	404 ^{ab}	10.2 ^{bc}	16.3 ^{ab}	2.15 ^{ab}
LER 15	-	5	386 ^{a}	11.5 ^{c}	16.0 ^{ab}	1.94 ^{a}

[1] Calculated using determined metabolizable energy values for the diets.

[2] Kilocalories of metabolizable energy consumed/kilocalorie gained.

[3] See footnotes 2 to 4, Table 9.

[4] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

Discussion

The failure of diets containing 20 parts LER to promote chick growth and energy intake equal to that of chicks fed diets containing 20 parts SFO when fed ad libitum is in contrast to results of Experiments 1 and 2. When results of the three experiments are combined (Table 15) and analyzed statistically, results showed that the growth promoting properties of the three oils do differ with SFO promoting the most rapid growth, HER the least rapid growth and LER an intermediate rate of growth. These results indicate that in chicks both the level of erucic acid and the level of saturated fatty acids contribute to the growth depressing properties of rapeseed oil. The finding in Experiment 3 that growth is stimulated by supplementation of the rapeseed oils with palmitic acid supports this concept.

Similar statistical treatment of the combined data on fat gain from the three experiments (Table 15) showed that chicks pair-fed diets containing either 20 parts LER or HER deposited significantly less fat than chicks fed diets containing SFO. These results indicate that fat deposition may also be affected by dietary intake of erucic acid and/or saturated fatty acids. The effect of HER but not LER on fat deposition was evident after chicks had been pair-fed the diets for only 7 days. Similar results were obtained in Experiments 1 and 2 when chicks were fed ad libitum for 7 days.

Table 15

Weight gain, fat gain and energy utilization of chicks fed diets containing 20 parts of experimental oils for 24 or 26 days.

Treatment			Ad libitum	Pair-fed	
Oil	Level	Exp. no.	Weight gain	Fat gain	Energy utilization[1]
	g		g	g	
HER[2]	20	1	435[3]	27.4	2.65
		2	429	28.2	2.74
		3	506	46.6	2.50
			457[a]	34.0[a]	2.63[b]
LER[2]	20	1	494	32.8	2.54
		2	477	28.7	2.60
		3	538	50.4	2.32
			503[b]	37.3[a]	2.49[a]
SFO[2]	20	1	502	38.3	2.44
		2	509	35.1	2.50
		3	595	56.3	2.26
			535[c]	43.2[b]	2.40[a]

[1] Kilocalories of metabolizable energy consumed/kilocalorie gained.

[2] See footnotes 2 to 4, Table 9.

[3] Values are averages of duplicate groups. Underlined values are averages of triplicate experiments. Values without a common letter in their superscript are significantly different ($P<0.05$).

PART 2

HEART AND CARCASS LIPIDS OF CHICKS FED RAPESEED OILS

Literature Review

It is now well established that rapeseed oil incorporated into diets of various animals causes pathological changes in heart and skeletal muscle both of which are predominantly dependent on fat for energy.

Studies have shown that the total lipid content of cardiac tissue of rats fed diets containing high erucic acid rapeseed oil starts to rise within 24 hours and reaches levels 3 to 4 times higher than those of a normal organ within one week. Abdellatif and Vles (1970a) showed that fatty acid infiltration of the heart muscle in rats occurred after only one day on a diet in which 50% of the energy was supplied by rapeseed oil. Houtsmuller et al. (1970) fed rats a diet in which 50% of the energy was supplied by rapeseed oil for periods varying from 1 day to 6 weeks. Within the first 3 days, a sharp increase in the lipid content of the heart was observed which was mainly due to an increase in triglycerides. The amount of free fatty acids also increased to more than twice its initial level. With time there was regression of this lipid accumulation though not to the control level. Beare-Rogers et al. (1971) also found a peak accumulation of cardiac fatty acids at 7 days

after feeding weanling rats a diet supplying 20% by weight of rapeseed oil. In studying the histopathological effects, they found the zero-effect level to be 5% by weight of rapeseed oil.

Roine et al. (1960) conducted histological studies on various organs in the rat after feeding diets containing rapeseed oil. When rapeseed oil supplied more than 50% of the energy in the diet, myocardial changes appeared within 6 weeks but when diets in which rapeseed oil supplied less than 30% of the energy were fed, no such effect was observed. Of the organs examined, only the heart revealed definite pathological changes. Rocquelin and Cluzan (1968), found that rats fed diets containing 15% rapeseed oil developed myocardial lesions within 7 months. Abdellatif and Vles (1970b) fed rats diets in which 30-60% of the energy was supplied by rapeseed oil and observed myocardial changes after 4 to 8 weeks. The lesions increased in severity up to 64 weeks.

Studies have also been conducted to compare the pathological effects of rapeseed oil and Canbra oil when incorporated in the diet of the rat. Beare-Rogers et al. (1971) and Rocquelin et al. (1971) observed that unlike rats fed rapeseed oil-containing diets, rats fed diets containing 10 to 20% Canbra oil did not accumulate excess quantities of fat in their hearts. However, Rocquelin and Cluzan (1968) and Rocquelin et al. (1973) did observe the

development of myocardial lesions in the absence of cardiac lipid accumulation when rats were fed diets containing 15% Canbra oil. Abdellatif and Vles (1970b) repeated the experiment of Rocquelin and Cluzan (1968) in which Canbra oil was found to cause myocardial lesions, but they were unable to induce these lesion after 24 weeks of feeding diets containing 15% Canbra oil. In addition, they observed no pathological changes after feeding diets containing 25 or 30% Canbra oil for 3 or 14 days, respectively, but did observe the characteristic lesions in rats consuming similar diets containing rapeseed oil.

Studies of the fatty acid composition of cardiac lipids have been reported by Beare-Rogers (1970) and Kramer et al. (1973). In weanling rats they observed a high concentration of erucic and eicosenoic acids in cardiac lipid within one week of feeding diets containing rapeseed oil.

That the pathological effects of rapeseed oil are due to its erucic acid content was shown by Abdellatif and Vles (1970a). They found that rats fed diets containing equicaloric amounts of erucic acid as glyceryl erucate or as rapeseed oil developed myocardial lesions. Recently, Beare-Rogers et al. (1972) using synthesized oils, have shown that erucic acid is the most important factor in rapeseed oil in producing the accumulation of cardiac lipids. Other factors in rapeseed oil which they found contributed to the

accumulation of cardiac lipid were eicosenoic acid and the low level of saturated fatty acids.

Studies have also shown that the physiological and pathological effects of rapeseed oil are affected by both the age and sex of the rat. Beare-Rogers and Nera (1972) found that rats at 12 weeks of age showed greater resistance to myocardial alteration and greater ability to metabolize long-chain fatty acids when fed rapeseed oil-containing diets than did weanling rats. After one week of feeding, they found that the older rats deposited smaller quantities of fatty acids in the heart than did weanling rats similarly treated. The concentration of erucic acid in these lipids decreased appreciably with increasing age. Deposition of eicosenoic acid also tended to decrease with age. More recently, Kramer et al. (1973) found a rapid build up of erucic acid (23%) in cardiac lipid of rats fed diets containing rapeseed oil for 1 week. The gradual decrease in erucic acid to 4% after 16 weeks on the diet which was observed, was attributed to adaptation.

Beare-Rogers et al. (1971) reported that absolute heart weights did not vary when rats were fed diets containing 20% rapeseed oil or a similar level of a lard/corn oil mixture for 3, 7, 14 or 28 days. Rapeseed oil in these diets would supply approximately 40% of the energy. Abdellatif and Vles (1973) showed that heart size was significantly greater when rats were fed diets in which 30% of the energy was supplied

by rapeseed oil and 10% by sunflowerseed oil, than when diets were fed in which energy was supplied by 25% or less rapeseed oil and correspondingly greater amounts of sunflowerseed oil. They also found that when the level of rapeseed oil in the diet was increased to supply 50% of dietary energy, heart size was significantly greater than when diets supplying a similar level of low erucic acid rapeseed oil or sunflowerseed oil were fed.

Skeletal muscle has also been shown to accumulate fat when rats were fed diets containing rapeseed oil. Abdellatif and Vles (1970a,1970b) showed that fatty infiltration of skeletal muscle occurred within 24 hours of rapeseed oil feeding, reaching a maximum after 3 to 6 days, but with time this regressed and normal morphology was regained. This is in contrast to cardiac muscle where normal morphology was not regained.

The effect of feeding diets containing rapeseed oil on the fatty acid composition of carcass fat of rats has also been studied. Craig et al. (1963b) fed rats diets containing 20% rapeseed oil. They found that the level of eicosenoic acid in the carcass fat resembled that of the rapeseed oil fed, while the amount of erucic acid was much lower (7%), than in the dietary oil (37%). Hopkins et al. (1957) compared the deposition of eicosenoic, erucic and oleic acids when fed as methyl esters to rats. Results showed that erucic acid was deposited in body fat in

considerably smaller amounts (approximately 12% of the fatty acids) than was eicosenoic acid (approximately 28% of fatty acids.)

In determining the cause of fat accumulation, Houtsmuller et al. (1970) demonstrated a reduced ability of isolated rat heart mitochondria to oxidize several substrates when rapeseed oil was the source of energy. Recently, Christophersen and Bremer (1972) examined the extra-cellular metabolism of erucic acid by studying oxygen uptake of rat heart mitochondria when erucyl- and palmitylcarnitine served as substrates. They concluded that erucic acid may inhibit the oxidation of other fatty acids causing them to be channeled into other pathways that are relatively less inhibited such as triglyceride synthesis. Support for this concept is their finding that the triglycerides which accumulated in the hearts of rats contained not only erucic acid but other fatty acids, and in relative proportions to that of the fat fed.

There are few reports on the physiological and pathological effects on chicks of feeding diets containing rapeseed oil. In regard to heart size, Sheppard et al. (1971) observed that the substitution of 16% rapeseed oil for a similar amount of dietary corn oil had no effect on heart size. In regard to the effect of rapeseed oil on fatty acid composition of body fat, Sell and Hodgson (1962) observed that chicks fed diets containing 4 or 8% rapeseed

oil deposited substantial amounts of eicosenoic and erucic acid in adipose tissue. Salmon (1969) reported that the level of erucic acid in carcass fat of chicks fed diets containing rapeseed oil was about 50% of that in the fat fed. He observed that little change in the levels of eicosenoic or erucic acid in carcass fat occurred between 6 and 40 days. This suggested an apparent ability of the chick partially to degrade erucic acid at or very soon after hatching. This is in contrast to the rat which appears to develop the capacity to oxidize erucic acid with increasing age.

Little attention has been paid to the lipid content and composition of cardiac tissue in chicks. Thus, the following studies were conducted to determine the effect that incorporating two types of rapeseed oil in the diet of the chick has on heart size, fat content of the heart, and fatty acid composition of cardiac and carcass lipid.

EXPERIMENT 4

The consumption of rapeseed oil has been shown to cause accumulation of fat in the heart and changes in its fatty acid composition in several animal species, including rats, monkeys and gerbils (Beare-Rogers and Nera 1972), and in ducklings (Abdellatif and Vles, 1970c). Since information on the effect of rapeseed oil on heart tissue of chicks is limited, the following studies were conducted to determine the effects on size, fat content and fatty acid composition of hearts, when chicks were fed diets containing high and low erucic acid rapeseed oils with and without altered ratios of saturated to unsaturated fatty acids. In addition, the fatty acid composition of carcass fat was studied.

Materials and Methods

In the course of preceding experiments, hearts were removed from the carcasses and stored at -29° C until analyzed. The hearts from each group were then cut into 1/8" slices, dried by lyophilization for approximately 24 hours, and moisture content determined by difference. The dried samples were maintained in a cool environment during grinding in a Wiley mill and subsequently stored at -29° C.

Samples were analyzed for fat content as described by

Hill and Anderson (1958). To determine fatty acid composition of heart and carcass fat, methyl esters were prepared by the method of Metcalfe et al. (1966). An Aerograph series 600 chromatograph with a four filament thermal conductivity detector (Model 664) was equipped with an aluminum column (10ftx1/4in. o.d.), packed with Silar 5CP on 80-100 mesh acid washed Chromosorb W. Peaks were identified by comparing retention times of unknown components with those of a known standard, and peak areas computed by geometric approximation. Fraction by weight of a component in a mixture was calculated by the formula proposed by Eastman (1957).

Results

Data showing the weight and fat content of hearts from chicks fed diets in which 10 or 20 parts HER, LER, or SFO were substituted isocalorically for glucose are shown in Table 16. Analysis of variance and application of Duncan's multiple range test (Steel and Torrie, 1960) to the data obtained after 7 days showed that the incorporation of 10 or 20 parts HER or LER in the diet of the chick had no consistent effect on heart weight when compared to the SFO fed controls, and no effect on fat content of the heart. When chicks were pair-fed or fed ad libitum for 24 days, the incorporation of 20 parts HER in the diet significantly increased heart weight when compared to those of chicks fed

Table 16

Weight and fat content of hearts[1] of chicks fed diets containing various oils (Exp.2).

Treatment		Ad libitum				Pair-fed	
		7 day		24 day		24 day	
Oil	Level	Heart size[2]	Fat content	Heart size[3]	Fat content	Heart size[2]	Fat content
	g	mg/g	%	mg/g	%	mg/g	%
High carbohydrate		9.69^{sbc}	7.47^{a}	5.91^{a}	10.25^{b}	-	-
HER[4]	10	8.99^{ab}	7.36^{a}	6.41^{a}	9.14^{a}	6.97^{a}	9.14^{a}
LER[4]	10	10.09^{c}	8.36^{a}	6.24^{a}	10.11^{ab}	6.59^{a}	10.23^{a}
SFO[4]	10	10.16^{c}	8.67^{a}	6.29^{a}	9.12^{a}	6.64^{a}	9.62^{a}
HER	20	9.12^{ab}	8.30^{a}	7.57^{b}	9.07^{a}	8.32^{b}	9.07^{a}
LER	20	8.56^{a}	7.60^{a}	6.42^{a}	9.12^{a}	6.46^{a}	9.89^{a}
SFO	20	9.71^{bc}	9.07^{a}	6.05^{a}	11.96^{c}	6.23^{a}	12.27^{b}

[1] Determined on a wet weight basis.

[2] mg heart/g carcass

[3] mg heart/g body weight

[4] See footnotes 2 to 4, Table 2.

[5] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different. ($P<0.05$).

diets containing 10 parts HER, LER or SFO, or 20 parts of LER or SFO. Analysis of hearts for their fat content showed that HER did not increase heart weight by increasing fat deposition. When chicks were pair-fed or fed ad libitum for 24 days, results showed that diets containing 20 parts SFO caused greater heart fat deposition than diets containing 10 parts SFO, HER or LER, or 20 parts HER or LER.

Results of Experiment 3 (Table 17) confirmed results obtained in Experiment 2, in showing that chicks fed diets containing 20 parts HER for 26 days had significantly larger hearts than did chicks fed diets containing 20 parts LER or SFO. In contrast to results of Experiment 2, chicks fed diets containing 20 parts SFO did not deposit any more fat in their hearts than did chicks fed diets containing 20 parts HER or LER.

Modification of the fatty acid composition of HER by the addition of palmitic acid decreased heart size in both pair-fed and ad libitum fed chicks after feeding the experimental diets for 26 days. No such effect was observed on addition of oleic acid to HER, or of palmitic or oleic acid to LER. In chicks fed the diets ad libitum for 26 days, increasing the palmitic acid content of HER reduced fat content of the heart significantly, but no such effect was observed when the diets were pair-fed. Modification of the fatty acid content of HER or LER by the addition of oleic acid did not affect the fat content of the heart,

Table 17

Weight and fat content of hearts[1] of chicks fed experimental diets (Exp.3).

Dietary level			Ad libitum		Pair-fed			
			26 day		7 day		26 day	
	Oil	Palmitic acid	Oleic acid	Heart size[2]	Fat content	Heart size[3]	Fat content	Heart size[3]	Fat content
	g	g	g	mg/g	%	mg/g	%	mg/g	%
SFO[4]	20	-	-	6.10[5a]	12.18[b]	8.72[a]	9.20[a]	6.36[a]	12.80[b]
HER[4]	20	-	-	7.20[c]	12.23[b]	9.40[a]	7.94[a]	7.93[c]	12.23[ab]
HER	15	5	-	6.65[b]	9.47[a]	8.99[a]	8.80[a]	6.82[ab]	11.59[ab]
HER	15	-	5	7.28[c]	10.87[ab]	8.85[a]	8.30[a]	7.45[bc]	11.55[ab]
LER[4]	20	-	-	6.29[ab]	10.22[ab]	8.77[a]	9.37[a]	6.57[a]	11.68[ab]
LER	15	5	-	6.16[ab]	9.25[a]	9.28[a]	9.80[a]	6.40[a]	10.40[a]
LER	15	-	5	6.48[ab]	10.31[ab]	9.50[a]	10.06[a]	6.60[a]	12.12[ab]

[1] Determined on a wet weight basis.

[2] mg heart/g body weight.

[3] mg heart/g carcass.

[4] See footnotes 2 to 4, Table 9.

[5] Values are averages of duplicate groups. Values without a common letter in their superscipt are significantly different ($P<0.05$).

significantly.

The effect of the incorporation of HER and LER in the diet of the chick on the erucic acid content of heart lipid is shown in Table 18 (Experiment 2). For comparative purposes, data on erucic acid content of carcass lipid are also shown. The data show that increasing the level of HER in the diet from 10 to 20 parts increased the erucic acid content of both heart and carcass fat, significantly, in chicks fed the diets for either 7 or 24 days. Increasing the level of LER in the diet from 10 to 20 parts had little or no effect on the erucic acid content of heart or carcass lipid.

Analysis of variance showed that the erucic acid content of heart lipid was significantly lower than carcass lipid after both 7 and 24 days on the experimental diet. This suggests that the heart is as capable of disposing of erucic acid as carcass tissue.

Since the erucic acid content of both carcass and heart lipid is much lower than the oils fed, it can be concluded that the chick has a marked ability to utilize erucic acid. Results summarized in Table 19 showed that in Experiment 2, increasing the level of HER or LER in the diet from 10 to 20 parts, increased the percent of ingested erucic acid which was oxidized. Analysis of variance of the factorial arrangement of treatments showed time to be a significant

Table 18

Erucic acid content[1] of heart and carcass fat of chicks fed experimental diets (Exp.2).

Treatment		Ad libitum				Pair-fed	
		7 day		24 day		24 day	
Oil	Level	Carcass	Heart	Carcass	Heart	Carcass	Heart
	g	%	%	%	%	%	%
HER[2]	10	5.3[3 d]	3.2[c]	-	3.2[b]	5.7[d]	3.2[bc]
LER[2]	10	2.1[b]	0.7[a]	-	0.8[a]	2.6[b]	1.0[a]
HER	20	7.9[f]	6.1[e]	-	5.0[c]	7.4[e]	5.0[d]
LER	20	2.7[bc]	0.8[a]	-	0.5[a]	3.6[c]	1.0[a]

[1] Percent of total fatty acids.

[2] See footnotes 2 and 3, Table 2.

[3] Values are averages of duplicate groups. Values for carcass and/or heart samples obtained for a given feeding regimen which do not have a common letter in their superscript are significantly different ($P<0.05$).

Table 19

Oxidation of ingested erucic acid by chicks fed experimental diets for 7 or 24 days (Exp.2).

Treatment		7 day ad libitum			24 day pair-fed		
Oil	Level	Ingested	Carcass content	Oxidized	Ingested	Carcass content	Oxidized
	g	g	g	%	g	g	%
HER[1]	10	4.10[2]	0.89[b]	78.3[b]	20.55	2.67[b]	87.0[bc]
LER[1]	10	0.82	0.38[a]	54.3[a]	3.86	1.27[a]	67.1[a]
HER	20	6.58	0.97[b]	85.3[c]	32.55	2.38[b]	92.7[c]
LER	20	1.31	0.41[a]	68.7[b]	5.95	1.11[a]	81.3[b]

[1] See footnotes 2 and 3, Table 2.

[2] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

factor with a greater percentage of ingested erucic acid being oxidized at 24 days than at 7 days.

The effect of modifying the fatty acid composition of HER and LER by the addition of palmitic or oleic acid on the deposition of erucic acid in the lipid of heart and carcass is shown in Table 20. Analysis of variance showed that modification of the fatty acid content of HER by the addition of oleic acid caused significantly less accumulation of erucic acid in both heart and carcass lipid than did the addition of palmitic acid at 26 days. Similar results were obtained at 7 days except that in the case of carcass lipid the decrease in erucic acid caused by the addition of oleic acid was not great enough to be significant. Modification of the fatty acid composition of LER by the addition of palmitic or oleic acid had no significant effect on erucic acid deposition at either 7 or 26 days.

Calculations of the percent of the ingested erucic acid which was oxidized showed that as in Experiments 1 and 2, chicks have a marked ability to oxidize this fatty acid (Table 21). Modification of HER or LER by the addition of palmitic or oleic acids did not affect the percentage of ingested erucic acid oxidized, significantly.

The effect of the incorporation of HER and LER in the diet of the chick on the eicosenoic acid content of heart

Table 20

Erucic acid content[1] of heart and carcass fat (Exp.3).

Dietary level			Ad libitum		Pair-fed			
			26 day		7 day		26 day	
	Oil	Palmitic acid	Oleic acid	Carcass	Heart	Carcass	Heart	Carcass	Heart
	g	g	g	%	%	%	%	%	%
HER[2]	20	-	-	-	9.5[3d]	8.9[d]	8.4[d]	11.8[c]	9.5[b]
HER	15	5	-	-	6.4[c]	8.2[d]	6.8[d]	13.0[d]	11.2[c]
HER	15	-	5	-	5.2[b]	6.9[d]	4.4[bc]	9.6[b]	9.1[b]
LER[2]	20	-	-	-	0.5[a]	2.9[bc]	0.8[ab]	2.0[a]	1.3[a]
LER	15	5	-	-	0.4[a]	1.3[ab]	0.7[a]	1.5[a]	1.0[a]
LER	15	-	5	-	0.4[a]	1.2[ab]	0.7[a]	1.2[a]	0.8[a]

[1] Percent of total fatty acids.

[2] See footnotes 3 and 4, Table 9.

[3] Values are averages of duplicate groups. Values for carcass and/or heart samples obtained for a given feeding regimen which do not have a common letter in their superscript are significantly different ($P<0.05$).

Table 21

Oxidation of ingested erucic acid by chicks pair-fed experimental diets for 7 or 26 days (Exp.3).

Dietary level			7 days			26 days		
Oil	Palmitic	Oleic	Ingested	Carcass content	Oxidized	Ingested	Carcass content	Oxidized
g	g	g	g	g	%	g	g	%
HER[1] 20	-	-	9.00[2]	1.06[b]	88.2[b]	51.99	6.00[b]	88.4[a]
HER 15	5	-	6.85	0.98[b]	84.4[b]	39.16	7.46[c]	81.0[a]
HER 15	-	5	6.80	0.92[b]	86.4[b]	39.30	5.41[b]	86.2[a]
LER[1] 20	-	-	1.12	0.42[a]	63.1[a]	6.59	1.06[a]	83.9[a]
LER 15	5	-	0.88	0.20[a]	78.0[ab]	5.14	0.82[a]	84.2[a]
LER 15	-	5	0.84	0.20[a]	77.0[ab]	4.94	0.66[a]	86.7[a]

[1] See footnotes 3 and 4, Table 9.

[2] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

and carcass lipid is shown in Table 22. Analysis of variance showed that after 7 days on the experimental diets, heart tissue contained significantly more eicosenoic acid than did carcass tissue. After 24 days, heart lipid was slightly but significantly lower in eicosenoic acid. Increasing the level of HER in the diet from 10 to 20 parts increased the deposition of eicosenoic acid in both the heart and carcass, significantly, at both 7 and 24 days. Small increases were also observed in the eicosenoic acid content of both heart and carcass tissue at both 7 and 24 days when the level of LER in the diet was increased from 10 to 20 parts. Since carcass lipid contained less eicosenoic acid than the lipid fed, eicosenoic acid must be oxidized. Results (Table 23) show that as with erucic acid, oxidation of eicosenoic acid increased with intake and with time.

The effect on deposition of eicosenoic acid of modifying the fatty acid composition of HER and LER is shown in Table 24. Analysis of variance of the factorial arrangement of treatments showed that modification of the fatty acid content of HER by the addition of oleic acid resulted in significantly less accumulation of eicosenoic acid in both heart and carcass tissue than did the addition of palmitic acid. Modification of the fatty acid composition of LER by the addition of either oleic or palmitic acid did not significantly affect deposition of eicosenoic acid in the heart and carcass of chicks pair-fed

Table 22

Eicosenoic acid content[1] of heart and carcass fat of chicks fed experimental diets (Exp.2).

Treatment		Ad libitum				Pair-fed	
		7 day		24 day		24 day	
Oil	Level	Carcass	Heart	Carcass	Heart	Carcass	Heart
	g	%	%	%	%	%	%
HER[2]	10	5.6[3d]	5.8[d]	-	6.9[b]	7.4[d]	6.9[d]
LER[2]	10	1.5[ab]	1.6[a]	-	2.0[a]	2.2[a]	2.2[a]
HER	20	7.8[e]	10.0[f]	-	9.5[c]	9.7[e]	9.5[e]
LER	20	2.4[c]	2.4[c]	-	2.2[a]	3.3[c]	2.7[b]

[1] Percent of total fatty acids.

[2] See footnotes 2 and 3, Table 2.

[3] Values are averages of duplicate groups. Values for carcass and/or heart samples obtained for a given feeding regimen which do not have a common letter in their superscript are significantly different ($P<0.05$).

Table 23

Oxidation of ingested eicosenoic acid by chicks fed experimental diets for 7 or 24 days (Exp.2).

Treatment		7 day ad libitum			24 day pair-fed		
Oil	Level	Ingested	Carcass content	Oxidized	Ingested	Carcass content	Oxidized
	g	g	g	%	g	g	%
HER[1]	10	1.90[2]	0.94[b]	50.5[a]	9.52	3.44[c]	68.8[b]
LER[1]	10	0.58	0.28[a]	51.4[a]	2.68	1.12[a]	58.4[a]
HER	20	3.04	0.97[b]	68.2[a]	15.08	3.14[b]	79.1[d]
LER	20	0.92	0.36[a]	60.7[a]	4.14	1.08[a]	74.0[c]

[1] See footnotes 2 and 3, Table 2.

[2] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

Table 24

Eicosenoic acid content[1] of heart and carcass fat (Exp.3).

Dietary level				Ad libitum		Pair-fed			
				26 day		7 day		26 day	
	Oil	Palmitic acid	Oleic acid	Carcass	Heart	Carcass	Heart	Carcass	Heart
	g	g	g	%	%	%	%	%	%
HER[2]	20	-	-	-	11.5[3d]	7.3^{cd}	10.0^{e}	11.8^{e}	11.5^{e}
HER	15	5	-	-	9.9^{c}	6.7^{bc}	8.1^{d}	9.9^{d}	10.3^{d}
HER	15	-	5	-	8.1^{b}	5.4^{b}	5.8^{b}	7.9^{c}	8.4^{c}
LER[2]	20	-	-	-	2.2^{a}	2.3^{a}	2.4^{a}	2.9^{b}	2.9^{b}
LER	15	5	-	-	2.1^{a}	1.7^{a}	2.1^{a}	2.3^{ab}	2.4^{ab}
LER	15	-	5	-	1.6^{a}	1.6^{a}	2.2^{a}	2.0^{a}	2.1^{a}

[1] Percent of total fatty acids.

[2] See footnotes 3 and 4, Table 9.

[3] Values are averages of duplicate groups. Values for carcass and/or heart samples obtained for a given feeding regimen which do not have a common letter in their superscript are significantly different ($P<0.05$).

the diets for 7 and 26 days. Calculations indicate that in this experiment chicks fed the diet supplying HER modified with palmitic acid for 26 days were less capable of oxidizing eicosenoic acid than similar diets modified with oleic acid (Table 25).

Discussion

The finding that chicks after consuming diets containing 20 parts HER for 24 days had average heart weights greater than chicks fed diets containing 20 parts SFO is in contrast to results reported by Sheppard et al. (1971) and by Beare-Rogers et al. (1971). Sheppard et al. (1971) found no difference between heart weights of chicks fed diets containing 16% rapeseed oil for 3 weeks and those fed diets containing 16% corn oil, when heart weight was expressed as a percentage of carcass weight. Beare-Rogers et al. (1971) observed no difference in heart weights of rats fed diets containing 20% rapeseed oil and those fed 20% of a lard-corn oil mixture for 3, 7, 14 and 28 days. The possibility exists that significant differences might have become apparent in Beare-Rogers' study if heart weight had been expressed as a percentage of body weight since the lard-corn oil fed rats were heavier.

Analysis showed that immediately prior to being placed on the test diets at 4 days of age, the fat content of chick heart was 4.16% on a wet weight basis. The increase to

Table 25

Oxidation of ingested eicosenoic acid by chicks pair-fed experimental diets for 7 or 26 days (Exp.3).

Dietary level			7 days			26 days		
Oil	Palmitic	Oleic	Ingested	Carcass content	Oxidized	Ingested	Carcass content	Oxidized
g	g	g	g	g	%	g	g	%
HER[1] 20	-	-	3.08[2]	0.86^{c}	72.0^{a}	18.83	6.00^{c}	68.1^{b}
HER 15	5	-	2.34	0.88^{bc}	62.6^{a}	14.19	5.68^{c}	60.0^{a}
HER 15	-	5	2.36	0.72^{b}	69.8^{a}	14.49	4.46^{b}	69.3^{b}
LER[1] 20	-	-	0.88	0.34^{a}	62.2^{a}	5.22	1.61^{a}	69.2^{b}
LER 15	5	-	0.70	0.26^{a}	63.3^{a}	4.08	1.26^{a}	69.1^{b}
LER 15	-	5	0.71	0.26^{a}	63.6^{a}	4.15	1.12^{a}	73.1^{b}

[1] See footnotes 3 and 4, Table 9.

[2] Values are averages of duplicate groups. Values without a common letter in their superscript are significantly different ($P<0.05$).

approximately twice this level after 7 days ad libitum feeding appears to be a normal physiological change since similar increases were observed irrespective of whether non-protein energy was supplied by carbohydrate or fat. A further increase was observed after the chicks had been fed the experimental diets for 24 days.

The finding in Experiments 2 and 3 that chicks fed diets containing 20 parts HER had not accumulated any more fat in their hearts after 7, 24 or 26 days than had chicks fed diets containing 20 parts SFO or an equicaloric amount of glucose, is in marked contrast to results reported for weanling rats. Houtsmuller et al. (1970), Rocquelin et al. (1971), Beare-Rogers et al. (1971) and Beare-Rogers and Nera (1972) reported that within a week, in rats fed diets in which rapeseed oil provided 30-50% of the energy, the total lipid content of cardiac muscle rose rapidly to levels 3 or 4 times higher than in a normal organ. At the peak of this accumulation they observed that erucic acid and eicosenoic acid made up 26-40% and 7-10% of the total fatty acids, respectively. Similar values for the chick after consuming diets containing HER for 7 days are 3-6% and 6-10% for erucic and eicosenoic acid, respectively (Tables 18 and 22). The data also show that levels of eicosenoic acid consistently exceed levels of erucic acid in cardiac lipids of the chick, while in rats the reverse occurs (Beare-Rogers et al., 1971; Beare-Rogers and Nera, 1972 and Kramer et al.,

1973).

These results indicate that heart tissue in the chick has a much greater ability to metabolize long-chain monounsaturated fatty acids than does the heart tissue of the rat, and that conversion of erucic acid to eicosenoic acid occurs at a faster rate in chicks than the conversion of eicosenoic acid to oleic acid. The reason why the addition of oleic acid caused a greater reduction in both erucic acid and eicosenoic acid (Tables 20 and 24) in cardiac and carcass lipid than did the addition of palmitic acid is not apparent.

GENERAL DISCUSSION

Nutritive value of high erucic acid rapeseed oil for the chick.

Studies have shown that in the chick as in the rat, high erucic acid rapeseed oil in excess of 10% by weight in the diet results in reduced feed intake and reduced growth. In contrast to the rat however, chicks fed rapeseed oil-containing diets did not accumulate cardiac lipid. Results showed that irrespective of whether non-protein energy was supplied by glucose, rapeseed oil or sunflowerseed oil, the level of fat in the hearts of chicks increased from 4.2% at 4 days of age to approximately 8% at 11 days and to approximately 10% at 28 days of age. In the case of rats fed diets containing rapeseed oil, studies have shown that there is accumulation of cardiac lipid within a few hours after the dietary regimen is started, which reaches a peak after 3 to 6 days, and thereafter decreases with time suggesting some form of adaptation by the animal (Abdellatif and Vles, 1970a; Rocquelin et al., 1973 and Kramer et al., 1973).

Analysis of the composition of cardiac lipids in weanling rats after inclusion of rapeseed oil in the diet, showed an increase in the proportions of erucic and eicosenoic acids. These levels then diminish with time suggesting that the capacity to utilize erucic and

eicosenoic acid increased with age (Beare-Rogers and Nera, 1972 and Kramer et al., 1973).

In the chick, there is also an increase in the proportion of erucic and eicosenoic acids in cardiac lipid after initiation of the rapeseed oil-containing diet, but not to the same extent as observed in the rat. Comparison of the level of erucic acid in heart and carcass lipids of chicks showed that heart lipid contained a significantly smaller proportion of erucic acid than did carcass lipid. In the case of eicosenoic acid, heart and carcass lipids contained similar levels. Thus, it can be concluded that in the chick, heart tissue is just as capable of disposing of both erucic and eicosenoic acid as carcass tissue.

In comparison, studies have shown that in rats, tissues vary in their ability to utilize erucic acid. Jaillard et al. (1973) compared levels of erucic acid in the lipid of heart, kidney and adipose tissue when rats were fed diets containing 10% trierucin. Results showed that the level of erucic acid in heart lipid was much higher than in either adipose or kidney lipid after 1 week of feeding. Levels of erucic acid in the lipid of these tissues decreased with time, the decrease being more marked in heart lipid. These results show that heart tissue is initially less able to oxidize erucic acid than is kidney or adipose tissue. Previously, Walker (1972) reported that the level of erucic acid in lipid of rats varied from tissue to tissue. He

found the greatest accumulation of erucic acid in the lipid of the adrenal gland, the least accumulation in brain lipid and intermediate amounts in the lipid of plasma, heart, spleen, kidney, liver, erythrocyte and testis. Walker's studies were conducted after rats had been fed the experimental diets for 18 weeks and thus would not reflect levels of erucic acid prior to adaptation.

Walker (1972) also studied the accumulation of eicosenoic acid in tissues of rats fed diets containing rapeseed oil for 18 weeks. He found the greatest accumulation in adrenal and spleen tissue, with lesser amounts in lipids of plasma, heart, kidney, liver, testis and brain. These results suggest that rat tissues may also vary in their ability to utilize eicosenoic acid.

Studies have shown that docosenoic acids fed to rats are oxidized via β-oxidation and result in increased levels of oleic acid in carcass lipids (Craig et al. 1963b; Craig and Beare, 1967). The activity of the pathway in rats is evident since results have shown that rats fed rapeseed oil incorporated only a small proportion of dietary erucic acid into tissue lipids (Walker, 1972).

In the case of chicks, studies have shown that they also have a marked ability to oxidize erucic and eicosenoic acids. Comparisons of intake and retention of erucic acid have shown that after 7, 24 or 26 days of consuming diets

containing 20 parts of rapeseed oil, chicks oxidized an average of 87 and 91%, respectively, of the ingested erucic acid. Lesser amounts of eicosenoic acid (70 and 74%, respectively,) were oxidized suggesting either that the oxidation of erucic acid resulted in some accumulation of eicosenoic acid or that ingested eicosenoic acid was not oxidized as readily as ingested erucic acid.

The substitution of 20 parts rapeseed oil (HER) for sunflowerseed oil in the diet of the chick has been shown, under conditions of equalized nutrient intakes, to decrease fat deposition and to decrease efficiency of utilization of energy when calories consumed per calorie gained was used as the criterion of efficiency. This criterion has not been used as a measure of energetic efficiency in rats fed rapeseed oil, however, Hornstra (1972) showed that oxygen consumption and water vapour loss of rapeseed oil-fed rats was consistently higher than that of rats fed the sunflowerseed oil-containing diet. Hornstra (1972) also observed that rats fed diets containing 31.5% rapeseed oil gained less per unit of digestible energy consumed and suggested that the lower efficiency of the rapeseed oil diet was caused by a slightly uncoupled oxidative phosphorylation and a greater heat increment. Other evidence that rapeseed oil may interfere with energy metabolism in at least some tissues of the rat is the finding of Houtsmuller et al. (1970) that inclusion of erucic acid in the diet of the

rat caused the mitochondria of the heart but not of the liver to malfunction. Whether the decreased energetic efficiency observed in chicks fed high erucic acid rapeseed oil containing diets was due to malfunctioning of the mitochondria and/or uncoupling of oxidative phosphorylation is unknown. The mechanism whereby rapeseed oil interfered with energy utilization in the chick deserves further study.

Studies have shown that the nutritive value of HER for the chick was increased by the addition of palmitic acid. Results showed that chicks fed diets containing 15 parts HER and 5 parts palmitic acid grew faster when fed ad libitum, utilized energy more efficiently when pair-fed and had smaller hearts than did chicks fed diets containing 20 parts HER. The addition of a comparable level of oleic acid to HER did not result in increased growth, increased energy utilization, or reduced heart size indicating that the changes observed on addition of palmitic acid were due to the palmitic acid itself and not to decreased levels of erucic acid. Beare et al. (1963) obtained similar results with rats. They showed that rate of growth of rats was positively correlated with the level of palmitic acid in the oil fed when erucic acid content of the oils was maintained constant.

The finding that the addition of oleic acid (5 parts) to a chick diet containing HER (15 parts), caused a greater reduction in the level of both erucic acid and eicosenoic

acid in cardiac and carcass lipid than did the addition of palmitic acid (5 parts), should be confirmed and an explanation sought.

Nutritive value of low erucic acid rapeseed oil for the chick.

Studies have shown that LER was equal in nutritive value to SFO when 10 parts of the respective oils were incorporated in the diet of the chick. When the level in the diet was increased to 20 parts, combined results of 3 experiments showed that chicks fed diets containing LER grew significantly faster than chicks fed diets containing HER, but significantly slower than chicks fed diets containing SFO.

In contrast, Walker et al. (1970) found that LER supported growth equal to that of tallow when incorporated in the diet of chicks at a level of 20%. In the case of rats, Abdellatif and Vles, 1970b; Rocquelin et al., 1970; Craig and Beare, 1968 and Kramer et al., 1973, found that diets containing 15 or 20% by weight of low erucic acid rapeseed oil promoted the same weight gain as diets containing similar levels of sunflowerseed oil, peanut oil, olive oil or corn oil, respectively.

That the decreased growth of chicks fed diets containing 20 parts LER was due to decreased appetite is

evident from the finding that when the nutrient intakes of chicks were equalized by pair-feeding, chicks fed diets containing LER grew at the same rate as chicks fed diets containing SFO.

Modification of the fatty acid composition of LER by the addition of palmitic acid failed to increase chick growth significantly. Calculations showed that the addition of palmitic acid to LER increased the saturated fatty acid content from 5.1 to 28.8% of total fatty acids. These results indicate that the chick, like the rat, tolerates a wide range of intakes of saturated fatty acids. Previously, Craig and Beare (1968) found that modification of the saturated fatty acid content of Canbra oil from 7.1 to 41.8% did not affect rat growth.

Combined results of three experiments showed that when chicks were pair-fed, they deposited significantly less carcass fat when fed diets containing 20 parts LER than when fed diets containing 20 parts SFO, however the decrease in fat deposition was not great enough to cause a significant reduction in energetic efficiency. In contrast, Craig and Beare (1968) showed that rats fed diets containing 20 parts Canbra oil deposited fat in amounts similar to rats fed diets containing 20 parts olive oil or 20 parts of a mixture composed of 3 parts Canbra oil and 7 parts lard. In chicks, modification of the fatty acid composition of LER by the addition of either oleic acid or palmitic acid did not

increase fat deposition, significantly. The reason why chicks fed LER-containing diets deposit less carcass fat than chicks fed diets containing SFO is unknown.

Results also showed that chicks fed diets containing 20 parts LER for 7, 24 or 26 days had heart sizes and cardiac lipid content equal to or less than those of chicks fed a diet containing 20 parts of SFO. Previously, Rocquelin and Cluzan (1968), Rocquelin et al. (1973), Beare-Rogers et al. (1971) and Beare-Rogers (1970) showed that rats fed diets containing 15 or 20% Canbra oil did not accumulate abnormal amounts of fat in the heart; however Rocquelin and Cluzan (1968), Rocquelin et al. (1973) did observe myocardial lesions in Canbra-fed rats, although the incidence and severity was less than in rats fed HER.

SUMMARY

1. Chicks fed diets containing 10 or 20 parts HER from 4-11 days of age showed depressed growth, decreased feed consumption and reduced fat deposition when compared to chicks fed diets containing similar levels of SFO. Type of oil at the levels fed had no consistent effect on heart size and no effect on level of cardiac lipid.
2. Studies showed that chicks fed diets containing 10 parts HER, LER or SFO from 4-28 days of age grew at the same rate, consumed similar amounts of feed and had hearts similar in size and fat content. However, chicks fed diets containing 10 parts HER deposited significantly less fat and utilized energy less efficiently than chicks fed diets containing similar levels of LER and SFO.
3. When fed diets containing 20 parts HER from 4 to 28 or 4 to 30 days of age, chicks gained less weight than those fed similar levels of LER or SFO. It was also shown that chicks fed diets containing 20 parts HER deposited less fat and utilized energy less efficiently than chicks pair-fed diets containing similar levels of SFO.
4. Results indicated that chicks consuming diets containing 20 parts HER from 4 to 28 or 4 to 30 days of age had significantly larger hearts than those fed

diets supplying the same levels of LER or SFO. However, this increase in heart weight could not be attributed to increased fat content as this was either equal to or less than that found in hearts of chicks fed diets containing LER and SFO, respectively.

5. Results obtained after 26 days on the diet, showed that in the chick, supplementation of HER with palmitic acid significantly increased rate of growth and efficiency of energy utilization, and significantly decreased heart size when compared with the unsupplemented HER. These results are attributed to an increased level of palmitic acid, as similar changes were not found in diets containing HER supplemented with a similar level of oleic acid.
6. When fed diets for 26 days in which HER was supplemented with oleic acid, chicks showed significantly less accumulation of erucic and eicosenoic acids in heart and carcass lipid than when palmitic acid was added to HER.
7. Chicks fed diets containing 10 or 20 parts LER from 4-11 days of age grew at the same rate, utilized energy as efficiently, and deposited similar amounts of fat in their hearts and carcasses as chicks fed diets containing 10 or 20 parts SFO, respectively.
8. Chicks fed diets containing 10 parts LER from 4-28 days of age showed weight gain, carcass fat

deposition, energy utilization, and heart size similar to that in chicks fed the same level of SFO.

9. When fed diets supplying 20 parts LER from 4 to 28 or 4 to 30 days of age, weight gain and carcass fat deposition were significantly less than in chicks fed 20 parts SFO; however, efficiency of energy utilization and heart size were similar.

10. When chicks were fed diets for 26 days in which LER was supplemented with either palmitic or oleic acid, there was no significant effect on growth, carcass fat deposition, energy utilization, heart size or heart fat content.

11. Supplementation of LER with palmitic or oleic acid did not alter the erucic or eicosenoic acid content of heart or carcass lipid.

12. Comparison of the fatty acid composition of heart and carcass lipids showed that irrespective of the type of rapeseed oil or modified oil mixture fed, or of the age of the chick, heart lipids contained less erucic acid than carcass fat. This indicated that chick heart tissue was as capable of disposing of erucic acid as carcass tissue.

13. Comparison of the amounts of ingested erucic and eicosenoic acid which were retained by chicks from 4 to 28 days of age indicated that irrespective of the type of rapeseed oil or modified oil mixture fed, that either erucic acid is oxidized more rapidly than

eicosenoic acid, or that erucic acid is oxidized more rapidly to eicosenoic acid than is eicosenoic acid to oleic acid.

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APPENDIX

Fatty acid composition of heart and carcass lipid of chicks fed experimental diets for 7 days (Exp.2).

Fatty acid		Percent of total fatty acids						
		High CHO[1]	10%			20%		
			HER[2]	LER[3]	SFO[4]	HER	LER	SFO
14:0	Carcass	0.9	0.7	0.6	0.9	0.4	0.5	0.8
	Heart	0.9	0.5	0.5	0.4	0.2	0.3	0.2
16:0	Carcass	30.7	22.2	19.9	23.4	12.9	12.9	18.2
	Heart	27.6	16.1	14.6	14.7	7.2	6.9	9.4
16:1	Carcass	11.6	-	-	-	-	-	-
	Heart	11.8	4.6	4.2	3.5	2.1	1.7	1.9
18:0	Carcass	7.3	6.6	6.1	8.4	5.1	4.8	8.1
	Heart	7.4	6.3	5.5	7.3	4.3	3.9	6.5
18:1	Carcass	44.3	49.9	58.3	34.4	48.1	61.7	31.0
	Heart	43.5	42.3	50.2	25.6	42.6	56.6	20.6
18:2	Carcass	3.9	8.2	9.8	24.5	15.4	12.4	29.3
	Heart	6.6	15.9	17.2	45.3	20.5	21.7	58.3
18:3	Carcass	-	0.9	1.0	-	2.3	1.7	-
	Heart	0.8	4.3	4.4	1.5	5.5	4.6	1.6
20:0	Carcass	-	-	-	0.2	-	-	0.2
	Heart	-	-	-	-	-	-	-
20:1	Carcass	0.4	5.6	1.5	0.5	7.8	2.4	0.2
	Heart	0.6	5.8	1.6	0.4	10.0	2.4	0.3
20:2	Carcass	0.8	0.6	0.7	0.8	-	1.0	0.5
	Heart	-	-	-	0.1	0.4	-	-
20:4	Carcass	-	-	-	-	-	-	-
	Heart	0.9	1.0	1.2	1.2	1.2	1.0	1.2
22:0	Carcass	-	-	-	1.7	-	-	3.8
	Heart	-	-	-	-	-	-	-
22:1	Carcass	-	5.3	2.1	5.3	7.9	2.7	8.0
	Heart	-	3.2	0.7	-	6.1	0.8	-

[1] High carbohydrate.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.

[4] Sunflowerseed oil.

Fatty acid composition of heart lipid of chicks fed experimental diets ad libitum for 24 days (Exp.2).

Fatty acid	Percent of total fatty acids						
	High CHO[1]	10%			20%		
		HER[2]	LER[3]	SFO[4]	HER	LER	SFO
14:0	0.6	0.3	0.3	0.3	0.1	0.2	0.1
16:0	25.0	12.0	10.6	13.3	5.6	5.5	8.0
16:1	10.7	1.4	2.3	1.8	0.7	0.8	-
18:0	6.4	5.5	5.3	7.3	4.3	3.9	5.4
18:1	49.1	46.8	54.3	23.4	46.5	59.3	21.3
18:2	6.7	18.9	19.2	51.8	22.1	21.5	63.9
18:3	0.5	3.3	4.2	0.3	4.9	4.7	0.2
20:0	-	-	-	-	-	-	-
20:1	0.5	6.9	2.0	-	9.5	2.2	-
20:2	-	-	-	-	0.1	-	-
20:4	0.4	1.6	1.0	1.9	1.1	1.5	1.1
22:0	-	-	-	-	-	-	-
22:1	-	3.2	0.8	-	5.0	0.5	-

[1] High carbohydrate.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.

[4] Sunflowerseed oil.

Fatty acid composition of heart and carcass lipid of chicks pair-fed experimental diets for 24 days (Exp.2).

Fatty acid		Percent of total fatty acids					
		10%			20%		
		HER[1]	LER[2]	SFO[3]	HER	LER	SFO
14:0	Carcass	0.6	0.6	1.2	0.6	0.5	0.8
	Heart	0.3	0.4	0.3	0.1	0.1	0.1
16:0	Carcass	15.2	15.2	21.9	9.2	7.9	15.3
	Heart	12.0	11.5	13.7	5.6	5.4	7.7
16:1	Carcass	-	-	-	-	-	-
	Heart	1.4	1.1	0.9	0.7	0.4	0.3
18:0	Carcass	5.8	5.6	9.4	4.3	4.3	8.8
	Heart	5.5	5.6	8.1	4.3	3.8	6.6
18:1	Carcass	52.3	60.4	29.8	54.1	66.5	29.6
	Heart	46.8	53.2	23.9	46.5	59.5	20.3
18:2	Carcass	10.7	10.9	24.0	12.4	11.5	26.1
	Heart	18.9	19.2	51.6	22.1	21.4	63.2
18:3	Carcass	1.4	1.4	0.5	1.5	1.2	0.8
	Heart	3.3	4.3	-	4.9	4.4	0.3
20:0	Carcass	0.3	0.3	0.5	0.3	0.4	0.6
	Heart	-	-	-	-	-	-
20:1	Carcass	7.4	2.2	0.7	9.7	3.3	1.4
	Heart	6.9	2.2	-	9.5	2.7	0.2
20:2	Carcass	-	-	-	-	-	-
	Heart	-	-	-	0.1	-	-
20:4	Carcass	-	-	-	-	-	-
	Heart	1.6	1.4	1.5	1.1	1.2	1.2
22:0	Carcass	0.6	0.8	4.3	0.6	0.7	5.2
	Heart	-	-	-	-	-	-
22:1	Carcass	5.7	2.6	7.8	7.4	3.6	11.4
	Heart	3.2	1.0	-	5.0	1.0	-

[1] High erucic acid rapeseed oil.

[2] Low erucic acid rapeseed oil.

[3] Sunflowerseed oil.

Fatty acid composition of heart and carcass lipid of chicks pair-fed experimental diets for 7 days (Exp.3).

Fatty acid		Percent of total fatty acids						
					HER +		LER +	
		SFO[1]	HER[2]	LER[3]	Palmitic acid	Oleic acid	Palmitic acid	Oleic acid
14:0	Carcass	0.6	0.5	0.5	0.6	0.8	0.5	0.8
	Heart	0.2	0.3	0.2	0.4	0.7	0.3	0.6
16:0	Carcass	16.5	13.5	13.0	22.1	13.9	17.5	10.7
	Heart	9.7	8.5	7.3	17.9	9.7	14.8	6.8
16:1	Carcass	2.1	3.0	2.4	3.9	3.7	3.2	3.6
	Heart	1.4	2.3	1.8	2.7	2.8	1.9	2.5
18:0	Carcass	8.7	5.5	3.4	5.1	4.9	4.5	4.7
	Heart	6.1	4.4	4.0	5.0	5.3	4.1	3.7
18:1	Carcass	29.2	38.1	61.4	35.4	48.2	54.7	58.8
	Heart	20.5	34.5	57.3	32.0	46.2	51.7	60.2
18:2	Carcass	32.3	19.7	12.7	15.6	14.5	14.3	15.7
	Heart	60.2	25.5	20.5	21.5	20.8	19.4	18.6
18:3	Carcass	-	3.3	1.5	2.4	1.6	2.4	2.7
	Heart	0.6	5.1	4.9	4.7	3.8	4.5	3.8
20:0	Carcass	0.2	-	-	-	-	-	-
	Heart	-	-	-	-	-	-	-
20:1	Carcass	-	7.3	2.3	6.7	5.4	1.7	1.6
	Heart	0.1	10.0	2.4	8.1	5.8	2.1	2.2
20:2	Carcass	-	0.1	-	-	-	-	-
	Heart	0.1	0.2	-	-	-	-	-
20:4	Carcass	-	0.1	-	-	-	-	0.1
	Heart	1.1	0.9	0.8	0.9	0.5	0.6	0.8
22:0	Carcass	4.0	-	-	-	-	-	-
	Heart	-	-	-	-	-	-	-
22:1	Carcass	6.4	8.9	2.9	8.2	6.9	1.3	1.2
	Heart	-	8.4	0.8	6.8	4.4	0.7	0.7

[1] Sunflowerseed oil.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.

Fatty acid composition of heart and carcass lipid of chicks pair-fed experimental diets for 26 days (Exp.3).

Fatty acid		Percent of total fatty acids						
					HER +		LER +	
		SFO[1]	HER[2]	LER[3]	Palmitic acid	Oleic acid	Palmitic acid	Oleic acid
14:0	Carcass	0.5	0.5	0.5	0.4	0.8	0.5	0.9
	Heart	0.1	0.2	0.2	0.3	0.6	0.3	0.6
16:0	Carcass	11.7	9.4	7.2	17.3	8.2	16.2	7.7
	Heart	7.5	6.6	4.8	16.0	6.5	13.1	5.4
16:1	Carcass	-	1.8	1.2	2.4	2.8	2.0	2.5
	Heart	0.6	1.4	0.9	1.8	2.3	1.4	2.1
18:0	Carcass	6.6	4.5	3.0	3.8	3.2	3.4	2.8
	Heart	5.4	3.9	3.5	4.0	3.5	3.6	3.2
18:1	Carcass	23.7	40.7	66.2	33.7	48.0	58.2	66.1
	Heart	19.0	36.0	59.8	30.7	44.9	54.2	63.1
18:2	Carcass	51.3	17.0	14.5	16.9	17.2	13.5	14.9
	Heart	66.2	25.0	21.1	21.2	20.5	19.0	18.4
18:3	Carcass	-	2.3	1.7	2.5	2.4	2.3	1.9
	Heart	0.2	5.0	4.7	3.8	3.5	4.1	3.5
20:0	Carcass	0.3	0.3	-	0.1	-	-	-
	Heart	-	-	-	-	-	-	-
20:1	Carcass	-	11.8	2.9	9.9	7.9	2.3	2.0
	Heart	0.2	11.5	2.9	10.3	8.4	2.4	2.1
20:2	Carcass	-	-	0.8	-	-	-	-
	Heart	-	0.2	-	-	-	-	-
20:4	Carcass	-	-	-	-	-	-	-
	Heart	0.9	0.8	0.8	0.8	0.7	0.8	0.7
22:0	Carcass	2.2	-	-	-	-	-	-
	Heart	-	-	-	-	-	-	-
22:1	Carcass	3.7	11.8	2.0	13.0	9.6	1.5	1.2
	Heart	-	9.5	1.3	11.2	9.1	1.0	0.8

[1] Sunflowerseed oil.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.

Fatty acid composition of heart lipid of chicks fed experimental diets ad libitum for 26 days (Exp.3).

Fatty acid	Percent of total fatty acids						
				HER +		LER +	
	SFO[1]	HER[2]	LER[3]	Palmitic acid	Oleic acid	Palmitic acid	Oleic acid
14:0	0.1	0.2	0.2	0.3	0.6	0.2	0.5
16:0	8.1	6.6	5.3	15.0	6.5	13.0	6.1
16:1	1.0	1.4	1.3	1.8	2.6	1.6	2.3
18:0	4.9	3.9	3.8	4.3	3.9	3.8	3.4
18:1	19.4	35.9	59.6	34.0	47.1	54.2	62.4
18:2	65.4	25.0	21.2	22.8	20.8	19.4	18.3
18:3	0.4	5.0	4.9	4.4	4.2	4.2	3.8
20:0	-	-	-	-	-	-	-
20:1	0.2	11.5	2.2	9.9	8.1	2.1	1.6
20:2	-	0.2	-	-	-	-	-
20:4	0.5	0.8	1.0	1.1	1.0	1.1	1.2
22:0	-	-	-	-	-	-	-
22:1	-	9.5	0.5	6.4	5.2	0.4	0.4

[1] Sunflowerseed oil.

[2] High erucic acid rapeseed oil.

[3] Low erucic acid rapeseed oil.